

XTB
U8835
V. 88
#1

ISSN 0038-3872

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

BULLETIN

Volume 88

Number 1



BCAS-A88(1) 1-44 (1989)

APRIL 1989

SHOUT **IT**
SHARE



Southern California Academy of Sciences

Founded 6 November 1891, incorporated 17 May 1907

© Southern California Academy of Sciences, 1989

OFFICERS

Camm C. Swift, *President*
June L. Siva, *Vice-President*
Hans M. Bozler, *Secretary*
Takashi Hoshizaki, *Treasurer*
Jon E. Keeley, *Technical Editor*
Gretchen Sibley, *Managing Editor*

BOARD OF DIRECTORS

1987-1989	1988-1990	1989-1991
Larry G. Allen	Sarah B. George	Takashi Hoshizaki
Hans M. Bozler	Margaret C. Jefferson	George T. Jefferson
Allan D. Griesemer	Susanne Lawrenz-Miller	David L. Soltz
Peter L. Haaker	John D. Soule	Camm C. Swift
June L. Siva	Gloria J. Takahashi	Robert G. Zahary

Membership is open to scholars in the fields of natural and social sciences, and to any person interested in the advancement of science. Dues for membership, changes of address, and requests for missing numbers lost in shipment should be addressed to: Southern California Academy of Sciences, the Natural History Museum of Los Angeles County, Exposition Park, Los Angeles, California 90007.

Annual Members	\$ 20.00
Student Members	12.50
Life Members	300.00

Fellows: Elected by the Board of Directors for meritorious services.

The Bulletin is published three times each year by the Academy. Manuscripts for publication should be sent to the appropriate editor as explained in "Instructions for Authors" on the inside back cover of each number. All other communications should be addressed to the Southern California Academy of Sciences in care of the Natural History Museum of Los Angeles County, Exposition Park, Los Angeles, California 90007.

Date of this issue 4 May 1989

THIS PUBLICATION IS PRINTED ON ACID-FREE PAPER.

Prevalence of Parasites in a Wild Population of the Pacific Harbor Seal (*Phoca vitulina richardsi*) from Gray's Harbor, Washington

Murray D. Dailey and Lori S. Fallace

*Ocean Studies Institute, Institute of Parasitology,
California State University, Long Beach, California 90840*

Abstract.—Over 6600 internal and external parasites representing eight species were recovered from 77 Pacific Harbor Seals *Phoca vitulina richardsi* collected in Gray's Harbor, Washington during a three year period.

Chi-square analysis indicates that the stomach nematodes *Pseudoterranova decipiens* and *Contracaecum osculatum* increased significantly with age of the host and were more prevalent in the spring months. The acanthocephalan *Corynosoma stromosum* was the most prevalent metazoan parasite recovered and appears well adapted to the northern seal populations. The nematode lungworm *Otostrongylus circumlitus* and cestode *Diphylobothrium alascense* were recovered from a single host each. The heartworm *Dipetalonema spirocauda* was found in 47 percent of seals examined along with a high incidence (45.5%) of the seal louse *Echinophthirius horridus*.

The Pacific Harbor Seal *Phoca vitulina richardsi* occurs in the eastern North Pacific from Baja California to the Aleutian Islands (King 1983). Captive and stranded harbor seals have been examined for parasitic infections (Stroud and Dailey 1978) but studies have not been carried out on wild populations (non-stranded) from a defined geographic region.

This study analyzes several parameters of the parasites recovered from 77 free-ranging seals collected from Gray's Harbor, located approximately in the middle of the Washington coastline, between July 30, 1976 and September 29, 1978.

Materials and Methods

Seals were collected each month of the year except January and November by the Washington Department of Fish and Game. A total of 39 females and 38 males were sampled, with ages ranging from one month to 22 years. Twenty-two of the 77 seals (#56-77) were incomplete (without stomach and intestine). Age determination was made from canine tooth stratification according to the methods of Scheffer (1950). The length and total weight of each individual were also recorded. Necropsies were carried out at the University of Puget Sound, Washington and all parasites from the intestinal tract (#1-55), stomach, liver, heart, lungs and skin collected. Parasites were fixed in 10 percent buffered formalin and shipped to California State University at Long Beach. The specimens were transferred to 70 percent ethyl alcohol and prepared for identification following standard procedures presented by Meyer and Olsen (1980). Anisakid nematodes were identified to stage according to Oshima (1972) and Shiraki (1974). Lice were

identified according to Ferris (1951). Voucher specimens are deposited at the Institute of Parasitology, California State University, Long Beach, California 90840.

Chi-square analysis was used to test the correlation between parasite prevalence and the following factors: host age, sex, season and year of collection. Chi-square was also used to examine frequencies of parasite species as well as total number of parasite species recorded from each host. Values were considered significant at $P < 0.05$, highly significant at $P < 0.01$, and very highly significant at $P < 0.001$.

Results

The Parasite Fauna

Over 6600 internal and external parasites which included five species of Nematode, and one species each of Cestoda, Acanthocephala, and Anaplura were recovered from the 77 seals.

Nematoda

The intestinal nematodes ($N = 55$) present were all ascaridoids consisting of *Anisakis simplex* (Rudolphi 1809) Baylis, 1920, *Pseudoterranova decipiens* (Krabbe 1878) Gibson and Colin, 1982 and *Contracaecum osculatum* (Rudolphi 1802) Baylis, 1920. A total of 103 larvae, 19 sexually immature adults and 9 adults of *A. simplex* were recovered. The combined prevalence was 18.2% with no significant differences found in age, sex or preference for season of the year (Tables 1, 2, and 3). *Anisakis simplex* also was found more frequently in animals with higher numbers of total parasite species (Table 5). *Pseudoterranova decipiens* was recovered from 13 seals (23.6%) and consisted of 17 larvae, 15 sexually immature adults, and 90 adult worms. A significant difference was found in the prevalence of this worm by host age, seasonality and year recovered (Tables 1, 3, and 4). Also, when prevalence of *P. decipiens* was correlated with the prevalence of other species it was found that *P. decipiens* occurred more frequently when *A. simplex* were present ($P < 0.0007$) (Table 5).

Twelve larval specimens of *P. decipiens* were found in the respiratory system (lung tissue, trachea, pulmonary artery) of four different seals. The seals ranged in age from one to 17 years. The prevalence of this nematode in these sites was not correlated with any specific age class or sex of the host, nor to season or year. However, it was found to occur more frequently in lungs of seals infected with three or more species of parasites ($P < 0.03$).

Contracaecum osculatum was found in only three (5.0%) seals (Table 2) and only during spring (Table 3). All three infected animals were females (Table 2), one six-year-old and two eleven-year-olds. No significant difference was found between *C. osculatum* and other parasite prevalences or between the total number of parasite species in the seals.

The heartworm *Dipetalonema spirocauda* (Leidy 1850) Anderson, 1959 was found in 36 of the 77 seals examined (46.8%). This parasite was recovered in all age classes except the six- and eight- to twelve-year-olds. It was most common in the one- to four-year-olds with approximately equal distribution between males and females (Tables 1 and 2). Summer samples contained the highest percentage of infected animals (54.3%) followed by fall, winter and spring (Table 3). The

Table 1. Prevalence of parasites by host age.

Parasite	Age of host												χ^{2b}	
	0-5 mo.	5-11 mo	1 yr.	2 yr.	3 yr.	4 yr.	5 yr.	6 yr.	7 yr.	8-12 yr.	13-17 yr.	18-22 yr.		
<i>A. simplex</i>	1/9	2/7	2/10	0/2	0/6	0/2	1/4	0/2	0/2	2/4	1/5	1/4	—	6.483 ^{ns}
<i>P. decipiens</i>	1/9	0/7	1/10	0/2	1/6	0/2	2/4	2/2	2/2	2/4	2/5	2/4	—	18.601*
<i>C. osculatum</i>	0/9	0/7	0/10	0/2	0/6	0/2	0/4	1/2	0/4	0/4	2/5	0/4	—	22.035*
<i>O. circumlitus</i>	1/11	0/10	0/12	0/5	0/7	0/3	0/7	0/2	0/2	0/4	0/7	0/7	0/2	6.079 ^{ns}
<i>D. spirocauda</i>	4/11	5/10	8/12	4/5	5/7	2/3	2/7	0/2	2/4	0/4	0/7	3/7	1/2	15.741 ^{ns}
<i>D. alascense</i>	0/11	0/10	1/12	0/5	0/7	0/3	0/7	0/2	0/4	0/4	0/7	0/7	0/2	5.488 ^{ns}
<i>C. stromosum</i>	7/9 ^a	7/7	9/10	2/2	6/6	1/2	4/4	2/2	4/4	5/5	4/4	4/4	—	11.174 ^{ns}
<i>E. horridus</i>	7/11	7/10	6/12	1/5	4/7	1/3	3/7	0/2	2/4	1/7	3/7	3/7	0/2	12.014 ^{ns}

^a Number of animals infected/number of animals examined.

^b Pearson chi-square statistic for homogeneity and its probability—* = $P < .05$, ns = not significant.

Table 2. Prevalence of parasites by host sex.

Parasite	Sex of host		χ^2 ^c
	Male	Female	
<i>A. simplex</i>	6/33 (18.2)	4/22 (18.2)	.000 ^{ns}
<i>P. decipiens</i>	6/33 (18.2)	7/22 (31.8)	.709 ^{ns}
<i>C. osculatum</i>	0/33 (0)	3/22 (13.6)	2.483 ^{ns}
<i>O. circumlitus</i>	0/41 (0)	1/36 (2.8)	.004 ^{ns}
<i>D. spirocauda</i>	21/41 (51.2)	15/36 (41.7)	.371 ^{ns}
<i>D. alascense</i>	1/41 (2.4)	0/36 (0)	.000 ^{ns}
<i>C. stromosum</i>	31/33 ^a (93.9) ^b	20/22 (90.9)	.000 ^{ns}
<i>E. horridus</i>	22/41 (53.7)	13/36 (36.1)	1.725 ^{ns}

^a Number of animals infected/number of animals examined.

^b Prevalence of infection—expressed as a percent.

^c Yates corrected chi-square value (for 2/2 frequency tables) and its probability as computed by Fisher's exact text (two/tailed).

only other parasites found to occur simultaneously with *D. spirocauda* at a significant level was *C. stromosum* and the seal louse *Echinophthirius horridus*.

Four *Otostrongylus circumlitus* (Raillet 1899) Bruyn, 1933 were recovered from the lungs of a single three-month-old female taken during September, 1977 (Table 1). This seal was also infected with a large number of *A. simplex* (108), with 34 *P. decipiens* and a heavy infestation of lice.

Cestoda

A single tapeworm, *Diphyllobothrium alascense* (Cobbald 1858) Rausch and Williamson, 1958 consisting of a 2 mm scolex and approximately 400 mm of strobila was recovered from a single one-year-old male collected during the summer sampling season. This seal also harbored a total of six different species of parasites, the highest number found in any individual (Table 5).

Acanthocephala

The acanthocephalan *Corynosoma stromosum* (Rudolphi 1802) Luhe, 1904 was the most prevalent parasite found in this study. Only four of the 55 infected

Table 3. Prevalence of parasites by season.

Parasite	Season of host capture				χ^2 ^c
	Winter	Spring	Summer	Fall	
<i>A. simplex</i>	3/12 (25.0)	2/8 (25.0)	4/24 (16.7)	1/11 (9.1)	1.273 ^{ns}
<i>P. decipiens</i>	0/12 (0)	4/8 (50.0)	8/24 (33.3)	1/11 (9.1)	9.335*
<i>C. osculatum</i>	0/12 (0)	3/8 (37.5)	0/24 (0)	0/11 (0)	18.642***
<i>O. circumlitus</i>	0/20 (0)	0/10 (0)	0/35 (0)	1/12 (8.3)	5.488 ^{ns}
<i>D. spirocauda</i>	9/20 (45.0)	2/10 (20.0)	19/35 (54.3)	6/12 (50.0)	3.748 ^{ns}
<i>D. alascense</i>	0/20 (0)	0/10 (0)	1/35 (2.9)	0/12 (0)	1.216 ^{ns}
<i>C. stromosum</i>	12/12 ^a (100.0) ^b	7/8 (87.5)	22/24 (91.7)	10/11 (90.9)	1.359 ^{ns}
<i>E. horridus</i>	14/20 (70.0)	2/10 (20.0)	10/35 (28.6)	9/12 (75.0)	15.722**

^a Number of animals infected/number of animals examined.

^b Prevalence of infection—expressed as a percent.

^c Pearson chi-square statistic for homogeneity and its probability—* = $P < .05$, ** = $P < .01$, *** = $P < .001$.

Table 4. Prevalence of parasites by year.

Parasite	Year of host capture			χ^2 ^c
	1976	1977	1978	
<i>A. simplex</i>	3/11 (27.3)	7/44 (15.9)	—	.764 ^{ns}
<i>P. decipiens</i>	0/11 (0)	13/44 (29.5)	—	4.256*
<i>C. osculatum</i>	0/11 (0)	3/44 (6.8)	—	.793 ^{ns}
<i>O. circumlitus</i>	0/11 (0)	1/46 (2.2)	0/20 (0)	.683 ^{ns}
<i>D. spirocauda</i>	4/11 (36.4)	26/46 (56.5)	6/20 (30.0)	4.495 ^{ns}
<i>D. alascense</i>	0/11 (0)	1/46 (2.2)	0/20 (0)	.683 ^{ns}
<i>C. stromosum</i>	11/11 ^a (100.0) ^b	40/44 (90.9)	—	1.078 ^{ns}
<i>E. horridus</i>	9/11 (81.8)	22/46 (47.8)	4/20 (20.0)	11.198**

^a Number of animals infected/number of animals examined.

^b Prevalence of infection—expressed as a percent.

^c Pearson chi-square statistic for homogeneity and its probability—* = $P < .05$, ** = $P < .01$.

animals examined in this investigation were without this worm. No significant difference was found in frequency of infection for this parasite regarding age, sex, season or year of collection (Tables 1, 2, 3, and 4). However, there was a very highly significant difference ($P < 0.001$) in the total number of parasite species found in the animals infected with *C. stromosum* (Table 5).

Anoplura

Echinophthirius horridus (Olfers 1816) Fahrenholz, 1919 was found infesting 35 of 77 seals examined (45.5%). These lice were most abundant during the fall and winter months, particularly during the first year of the study (Tables 3 and 4). All age groups of the host were infested except the age classes making up the smallest sample size, the six-year-olds and the 18- to 22-year-olds (Table 1).

Discussion

Parasites from *Phoca vitulina* have been previously listed by other authors (Margolis and Dailey 1972; Dailey and Brownell 1972; Dailey 1975; Stroud and Dailey 1978). However, most of these lists do not distinguish between moribund beach cast, dead, or free-ranging host seals. They also do not distinguish samples collected between open coast and embayment. The Margolis and Dailey (1972) publication covers an annotated list of marine mammal parasites from the west coast of North America while Stroud and Dailey (1978) report on only dead (beach cast) animals from the Oregon coast. The present study is the first conducted on parasites from free-ranging harbor seals from an embayment along the eastern Pacific coast. It is also the first study on *P. vitulina* from the Washington coast to correlate infection with age, sex and season of the host.

The common ascaridoids *Anisakis simplex*, *Pseudoterranova decipiens* and *Contracaecum osculatum* are currently undergoing taxonomic revisions. These changes have been discussed recently by Gibson (1983) and Lauckner (1985). *Anisakis simplex*, *C. osculatum* and *P. decipiens* are, by far, the most frequent stomach nematodes of pinnipeds. They are cosmopolitan in distribution, and have similar life cycles involving small planktonic crustaceans and teleost fishes (also squids) as first and second intermediate hosts respectively (Van Thiel 1976). *Anisakis simplex* was found to occur without preference to season, host age or host sex in

Table 5. Prevalence of parasites by total number of parasite species per host.

Parasite	Total number of parasite species						χ^2 ^c
	0	1	2	3	4	5	6
<i>A. simplex</i>	0/2 (0)	0/8 (0)	0/14 (0)	2/18 (11.1)	4/7 (57.1)	3/5 (60.0)	1/1 (100.0)
<i>P. decipiens</i>	0/2 (0)	0/8 (0)	2/14 (14.3)	4/18 (22.2)	4/7 (57.1)	2/5 (40.0)	1/1 (100.0)
<i>C. osculatum</i>	0/2 (0)	0/8 (0)	0/14 (0)	2/18 (11.1)	1/7 (14.3)	0/5 (0)	0/1 (0)
<i>O. circumlitus</i>	0/2 (0)	0/8 (0)	0/14 (0)	0/18 (0)	1/7 (14.3)	0/5 (0)	0/1 (0)
<i>D. spirocauda</i>	0/2 (0)	1/8 (12.5)	6/14 (42.9)	13/18 (72.2)	3/7 (42.9)	5/5 (100.0)	1/1 (100.0)
<i>D. alascense</i>	0/2 (0)	0/8 (0)	0/14 (0)	0/18 (0)	0/7 (0)	0/5 (0)	1/1 (100.0)
<i>C. stromosum</i>	0/2 ^a (0) ^b	7/8 (87.5)	14/14 (100.0)	18/18 (100.0)	6/7 (85.7)	5/5 (100.0)	1/1 (100.0)
<i>E. horridus</i>	0/2 (0)	0/8 (0)	5/14 (35.7)	13/18 (72.2)	6/7 (85.7)	5/5 (100.0)	1/1 (100.0)

^a Number of animals infected/number of animals examined.^b Prevalence of infection—expressed as a percent.^c Pearson chi-square statistic for homogeneity and its probability—* = $P < .05$, ** = $P < .01$, *** = $P < .001$.

this study. However, there was a correlation in prevalence of *A. simplex* in animals with a higher number of total parasite species. This suggests that infections by more than one species are more common than infections by single species and could reflect a dietary preference (bottom-dwelling fish) or indicate that seals with exposure through similar diets do not have a cross resistance to various ascaridoid (*A. simplex*, *P. decipiens*, *C. osculatum*) infections (McClelland 1980).

Pseudoterranova decipiens infections were found to increase with age and body weight of the host during this study. This finding seems logical given the increased food consumption as well as a larger fish size consumed by the host during the adult years. The present study also reveals a higher prevalence of *P. decipiens* in the spring (March through May) than any other season. This would verify McClelland's (1980) hypothesis that free-ranging seals do not develop resistance to reinfection with *P. decipiens*, although they may shed anisakine infections during periods of prolonged fasting such as those which occur during annual breeding and molting seasons (June and July). Therefore, infection rates would be at their highest after the seals' active feeding season, but prior to summer fasting.

The finding of immature *P. decipiens* in lung tissue, trachea, and pulmonary artery most probably is the result of ascaridoid worm migration normally carried out during its life cycle. This result may also be explained by postmortem migration which is common in stomach roundworms.

Contracaecum osculatum was found in only three older females (6 and 11 years) of the sample (55) examined. Also, the parasite was found in the spring of the year which may suggest also a shedding of these nematodes during the summer fasting period. This parasite has been previously reported along the west coast. Stroud and Dailey (1978) found one of 18 dead harbor seals examined along the Oregon coast infected with this worm. It also has been found in the stomach, intestine, and brain of *P. vitulina* along the California coast (Flores-Barrotta et al. 1961). It should, therefore, be considered a normal occupant of the pinniped gut along the west coast of North America and probably throughout the northern hemisphere (Valtonen et al. 1988). No significant difference was found between *C. osculatum* prevalence and total number of parasite species found during this study.

Otostrongylus circumlitus is called the "large lungworm" of phocid pinnipeds and is common in *Phoca vitulina* in European waters (Clausen 1978; Reijnders et al. 1981) and also from the North American Atlantic Coast (Dunn and Wolke 1976; Geraci 1978). It has also been recorded from other phocids (*Pusa hispida*, *Histiophoca fasciata*, *Mirounga angustirostris*, *Erignathus barbatus*) taken in North Pacific and Arctic waters (Popov 1975; Yurakhno and Treshchev 1975). It is obviously a common parasite in this host and little can be deduced from the single worm recovered during this study.

The heartworm *Dipetalonema spirocauda* was found in 36 of the 77 seals examined (46.8%). This filaroid infects a large number of pinniped species and is common in both feral and captive *Phoca vitulina* throughout the seal's distribution (King 1964; Nakamura and Mikami 1967; Delyamure et al. 1976). Van den Broek (1963) found 31 of 48 *P. vitulina* infected with *D. spirocauda* in Dutch waters. Stroud and Dailey (1978) found two of 18 *P. vitulina* infected with this species (reported as *Skjabinaria spirocauda*) from Oregon. In that study (Stroud

and Dailey) the infection was not correlated with sex of host, season or year, but the parasite did occur more frequently in young animals from five months to three years of age. Such a finding may be partially explained by the interesting correlation reported for the seal louse *E. horridus*. The Fisher's exact test (Brown 1981) showed that the only other parasite with vector potential to occur simultaneously with *D. spirocauda* at a significant level was *E. horridus*. This finding supports the hypothesis that the presence of one species of parasite is dependent upon the presence of the other species. One explanation provided by Geraci et al. (1981) is that *E. horridus* may serve as an intermediate host for *D. spirocauda*. During this study the highest prevalence of *D. spirocauda* infection was in the hosts collected during the summer, coinciding with the cycle of the vector population.

The low prevalence of cestodes in this free-ranging population may suggest a lower proportion of pelagic crustaceans and teleost fishes (intermediate hosts) in the diet of these seals. The fact that only a single specimen of *D. alascense* was recovered from this entire survey raises an interesting question. Inasmuch as *D. alascense* was originally described from dogs (not seals) in an Eskimo village by Rausch and Williamson (1958), it is possible that this record represents an accidental infection. The worm in this study was recovered from a one-year-old male which harbored six different species of parasites. It is conceivable that the animal was predisposed to an infection by this species because of a lowered resistance as a result of a heavy worm burden.

In the northern hemisphere *C. stromosum* is the most widely distributed species of Acanthocephala in ocean populations, infecting 13 different pinnipeds (Delyamure et al. 1976). In this study 93 percent of the seals examined harbored this species. *Corynosoma stromosum* appears to be most prevalent in northern waters with a decrease as one moves south. Margolis (1956) found a 100% infection in 12 harbor seals examined in Canada; 93% of the Washington seals were infected (this study); 34% in Oregon (Stroud and Dailey 1978) and 11% in California (Dailey and Hill 1970). This gradient suggests a preference by the parasite for intermediate hosts occurring in cooler waters.

The conclusions of this study indicate that the gut ascaridoid nematodes in harbor seals are common in all populations, be it open coastline or embayment. The acanthocephalan *C. stromosum* is a northern species of acanthocephalan that appears well adapted to the intermediate hosts found throughout the northwest. This does not appear to be the case with the lungworm, *O. circumlitus*, and cestode, *D. alascense*. The conditions for these worms to flourish, or at least appear in moderate numbers in the Gray's Harbor sample, apparently do not exist. This may be due to lack of intermediate hosts or dietary choice on the part of the seals. Further studies would have to be conducted to resolve this question. The heartworm *D. spirocauda* life cycle appears to be well established in this population of seals, given the results of this study.

Acknowledgments

The authors thank Dr. Murray Johnson and Mr. Steven Jeffries, University of Puget Sound, Washington for the collection and shipment of parasites. Our thanks also to Dr. Mas Dojiri, Institute of Parasitology, California State University, Long

Beach and Dr. Larry Shults, Wildlife International Ltd., Easton, Maryland, for reviewing the manuscript.

Literature Cited

- Brown, M. B. 1981. Two-way frequency tables—measures of association. In BMDP statistical software. (W. J. Dixon and M. B. Brown, eds.), University of California Press, Berkeley, California, 725 pp.
- Clausen, B. 1978. Diseases and toxochemicals in the common seal in Denmark. Riistat. Julk., 37: 38–39.
- Dailey, M. D. 1975. The distribution and intraspecific variation of helminth parasites in pinnipeds. Rapp. P.-V. Reun. Cons. Int. Explor. Mer, 169:338–352.
- , and B. L. Hill. 1970. A survey of metazoan parasites infecting the California (*Zalophus californianus*) and Steller (*Eumetopias jubatus*) sea lion. Bull. So. Calif. Acad. Sci., 69:126–132.
- , and R. L. Brownell. 1972. A checklist of marine mammal parasites. Pp. 528–589 in Mammals of the sea, biology and medicine. (S. H. Ridgway, ed.), Thomas, Springfield, Illinois, 812 pp.
- Delyamure, S. L., M. V. Yurakhno, and V. N. Popov. 1976. On the helminth fauna of pinnipeds from the Karaginsk Gulf (the Bering Sea). (In Russian; Engl. summary), Parazitologiya, 10: 325–332.
- Dunn, J. L., and R. E. Wolke. 1976. *Dipetalonema spirocauda* infection in the Atlantic harbor seal (*Phoca vitulina concolor*). J. Wildl. Dis., 12:531–538.
- Ferris, G. F. 1951. The sucking lice. Mem. Pac. Coast Entomol. Soc., 1:1–320.
- Flores-Barrotta, L., E. Hidalgo-Escalante, and R. Oleac. 1961. Nematodes from birds and mammals. IV (1). Erratic parasitosis in *Zalophus californianus* from Asuncion Island, Baja California, Mexico. Helmenthologia, 3:112–116.
- Geraci, J. R. 1978. The enigma of marine mammal strandings. Oceanus., 21:38–47.
- , J. F. Fortin, D. J. St. Aubin, and B. D. Hicks. 1981. The seal louse, *Ecinophthirus horridus*: an intermediate host of the seal heartworm, *Dipetalonema spirocauda* (Nematoda). Can. J. Zool., 59:1457–1459.
- Gibson, D. I. 1983. Concepts in Nematode Systematics. Pp. 321–338 in Systematics association special volume no. 22. (A. R. Stone, H. M. Plott, and L. F. Khalil, eds.), Academic Press, London and New York.
- King, J. E. 1964. Seals of the world. British Museum (Natural History), London, 154 pp.
- . 1983. Seals of the world (second edition). British Museum (Natural History), London, 240 pp.
- Laukner, G. 1985. Diseases of mammalia: Pinnipedia. Pp. 683–772 in Diseases of marine animals, Vol. IV, Pt. 2. (Kinne, ed.), Biologische Anstalt Helgoland, Hamburg, 341 pp.
- Margolis, L. 1956. Parasitic helminths and arthropods from Pinnipedia of the Canadian Pacific coast. J. Fish. Res. Bd. Canada, 13:489–505.
- , and M. D. Dailey. 1972. Revised annotated list of parasites from sea mammals caught off the west coast of North America. U.S. Dept. of Commerce; NOAA. Technical report NMFS. SSRF-647, 23 pp.
- McClelland, G. 1980. *Phocanema decipiens*: molting in seals. Expl. Parasit., 49:128–136.
- Meyer, M. C., and O. W. Olsen. 1980. Essentials of parasitology. Third edition. W. C. Brown Co., Dubuque, Iowa. 266 pp.
- Nakamura, S., and N. Mikami. 1967. Filariasis (*Dipetalonema spirocauda*) in a harbor seal. (In Japanese; Engl. summary). J. Jap. Ass. Zool. Grad. Aquar., 9:51–52.
- Oshima, T. 1972. Anisakis and anisakiasis in Japan and adjacent area. Progr. Med. Parasitol. Jpn., 4:301–393.
- Popov, V. N. 1975. On helminth fauna of the Sakhalin population of *Phoca vitulina largha*. (In Russian; Engl. summary). Zool. Zh., 54:769–770.
- Rausch, R. L. and F. S. L. Williamson. 1958. Studies on the helminth fauna of Alaska XXXIII. The description and occurrence of *Diphyllbothrium alascense* n. sp. (Cestoda). Z. Tropenmed. Parasit., 9:64–72.
- Reijnders, P. J. H., B. Clausen, J. C. Van Haaften, and J. Van der Kamp. 1981. Diseases and parasites in harbor seals of the Wadden Sea. Pp. 33–37 in Marine mammals of the Wadden Sea. (P. J.

- H. Reijnders and W. J. Wolff, eds.), Final Report of the Section "Marine Mammals" of the Wadden Sea Working Group. Rijksinst. Voor Nalucirheheer, Texel, Netherlands. pp. 38-47.
- Scheffer, V. B. 1950. Growth layers on the teeth of Pinnipedia as an indication of age. *Science*, 112: 309-311.
- Scheffer, T. H., and C. C. Sperry. 1931. Food habits of the Pacific harbor seal, *Phoca richardii*. *J. Mamm.*, 12:214-226.
- Shiraki, T. 1974. Larval nematodes of the family Anisakidae (Nematoda) in the Northern Sea of Japan. *Acta Med. et. Biol.*, 22:57-98.
- Stroud, R. K., and M. D. Dailey. 1978. Parasites and associated pathology observed in pinnipeds stranded along the Oregon coast. *J. Wildl. Dis.*, 14:292-298.
- Valtonen, E. T., H. Fagerholm, and E. Helle. 1988. *Contracaecum osculatum* (Nematoda: Anisakidae) in fish and seals in Bothnian Bay (Northeastern Baltic Sea). *Int. J. Parasitol.*, 18:365-370.
- Van den Broek, E. 1963. Mededelingen betreffend parasitologisch onderzoek bij de gewone zeehond, *Phoca vitulina* L. *Meded. Rijksmus. Gesch. Natuurw.*, 42:1-4.
- Van Thiel, P. H. 1976. The present state of anisakiasis and its causative worms. *Trop. Geogr. Med.*, 28:75-85.
- Yurakhno, M. V., and V. V. Treshchev. 1975. A survey of the helminth fauna of *Erignathus barbatus*. (In Russian). *Problemy Parazit.*, 1975, 301-302.

Accepted for publication 1 November 1988.

A Key to the Palaemonid Shrimp of the Eastern Pacific Region

Mary K. Wicksten

*Department of Biology, Texas A&M University,
College Station, Texas 77843*

Abstract. — Since the publication of the keys in the monographic study of American palaemonid shrimp by Holthuis (1951, 1952), numerous range extensions have been found, two new genera and seven new species have been described, and a taxonomic revision has added three genera to the family in the eastern Pacific. An up-to-date annotated key is provided to the 48 eastern Pacific species.

Caridean shrimp of the family Palaemonidae are common in intertidal and shallow subtidal rocky habitats, particularly in marine tropical and subtropical regions. Many are commensals of larger marine invertebrates, while others are facultative cleaners of marine fishes (Reynolds 1977; McCourt and Thomson 1984). The large "river prawns" of the genus *Macrobrachium* are edible, and are being studied for their potential for aquaculture.

To date, the most comprehensive works on eastern Pacific palaemonids have been those of Holthuis (1951, 1952). Since the publication of these valuable monographs seven new species have been described, a species has been introduced from the Orient and numerous range extensions have been found. In addition, a recent taxonomic revision of the family includes those genera previously separated into a distinct family, the Gnathophyllidae, into the Palaemonidae as members of the subfamilies Gnathophyllinae and Hymenocerinae (Bruce 1986a).

Most of the eastern Pacific palaemonids belong to genera that are widespread in tropical and warm temperate regions. Species of *Chacella*, *Veleronia* and *Waldola* are endemic to the tropical eastern Pacific. Species of *Harpiliopsis*, *Fennera* (associated with corals, *Pocillipora* spp.), *Pontonides* and *Allopontonia* occur from the eastern Pacific into the tropical Indo-West Pacific, but not in the Caribbean. Species of *Anchistoides*, *Coutierea*, *Lipkebe*, *Troglocubanus* and *Tuleariocaris* have been found in the Caribbean region, but not in the eastern Pacific. Also absent from the eastern Pacific are species of *Leander*, associated with drifting *Sargassum* in other parts of the world.

While examining specimens at the Allan Hancock Foundation (AHF), University of Southern California, and the California Academy of Sciences (CAS), I found range extensions of five species. These range extensions are presented herein, along with up-to-date records of the species from the literature. Records for ranges are taken from Wicksten 1983 except as noted. Numbers at the end of sections refer to notes at the end of the key.

I thank A. J. Bruce, Northern Territory Museum of Arts and Sciences, Darwin, Australia, for his valuable advice and information on ranges.

Key to the Marine Palaemonid Shrimp of the Eastern Pacific

1. Mandible without incisor process. Third maxillipeds expanded, leaf-like 2
 - Mandible usually with incisor process. Third maxillipeds not expanded, leaf-like 4
2. Last two articles of third maxilliped almost as broad as or broader than antepenultimate article, the latter distinctly broader than article preceding it. Dactyl of second leg serrate above. In life, colored brightly with contrasting red spots on white background
 - *Hymenocera picta* Dana. Widespread in Indo-Pacific, Panama (Mortensen 1918, as *Hymenocera* sp.) (1)
 - Last two articles of third maxilliped less than half as broad as the antepenultimate article; the latter about as broad as article preceding it. Dactyl of second pereopod not serrate above 3
3. Exopod of third maxilliped shorter than endopod. Dactyls of last three pereopods biunguiculate. (Robust, compact body, brightly colored in life) *Gnathophyllum panamense* Faxon. Gulf of California to Galapagos
 - Exopod of third maxilliped much longer than endopod. Dactyls of last three pereopods ending in simple claws. (Body not as robust, color inconspicuous)
 - *Gnathophylloides mineri* Schmitt. Circumtropical, Isla Malpelo. Commensal with sea urchins (Abele 1975)
4. Posterior margin of telson with 2 pairs spines. Pleurobranch on third maxilliped 5
 - Posterior margin of telson with 3 pairs spines. No pleurobranch on third maxilliped 27
5. Hepatic spine present, branchiostegal spine absent 6
 - Hepatic spine absent, branchiostegal spine present or absent 18
6. Dactyls of last 3 pereopods biunguiculate. Strictly marine, rocky bottoms or among coral
 - ... *Brachycarpus biunguiculatus* (Lucas). Circumtropical, Gulf of California to Colombia, Galapagos Islands
 - Dactyls of last three pereopods simple. Fresh and estuarine waters on sand, mud, gravel and rocky rubble 7
7. Carpus of second pereopod distinctly shorter than merus 8
 - Carpus of second pereopod as long as or longer than merus 10
8. Adult male with chelae of second pereopods very unequal in size and shape
 - *Macrobrachium hancocki* Holthuis. Costa Rica to Colombia, Cocos Island, Galapagos (Holthuis 1952)
 - Adult male with chelae of second pereopods equal in shape, usually equal in size 9
9. Small, up to 105 mm long. Second pereopods of male distinctly different in shape. Ventral surface of merus, carpus and palm of large chela with thick pubescence
 - ... *Macrobrachium inca* Holthuis. Rivers and streams of Ecuador and Peru (Holthuis 1952)

- Larger, up to 233 mm long. Second pereopods of male similar in shape. Ventral surface of merus, carpus and palm of large chela without thick pubescence except along cutting edge of fixed finger
 ... *Macrobrachium americanum* (Bate). Baja California and Sonora, Mexico to Peru and Galapagos Islands, usually in fresh water
- 10. Telson gradually tapering towards slender tip, which overreaches posterior telson spines
 ... *Macrobrachium panamense* Rathbun. Honduras to Ecuador, fresh water (Holthuis 1952)
- Telson not gradually tapering towards slender tip, posterior telson spines overreaching posterior margin 11
- 11. Second chelae of male very unequal in size and shape. Smaller chela with fingers strongly gaping 12
- Second chelae of male equal or subequal in shape. Smaller of 2 chelae, if one is smaller, never with fingers gaping 13
- 12. Both cutting edges of fingers of larger second chela having one large tooth, with 1–2 small teeth proximal to it. Rostrum curved upward at tip . *Macrobrachium digueti* (Bouvier). Baja California and Sinaloa, Mexico south to Peru, usually in fresh water
- Cutting edge of movable finger only of larger second chela having one large tooth, with 3 small teeth proximal to it. Rostrum not curved upward at tip *Macrobrachium acanthochirus* Villalobos 1966. Oaxaca and Colima, Mexico, fresh water
- 13. Cutting edges of fingers of large chela of adult male with 1–2 large proximal teeth, edges distal to these entire 14
- Cutting edges of fingers of large chela of adult male with numerous denticles of about equal size, without 1–2 large proximal teeth 16
- 14. Fingers of second chela of adult male $0.8\text{--}1.0\times$ as long as palm. Rostrum with proximal part of upper margin somewhat convex
 ... *Macrobrachium tenellum* (Smith). Southern Baja California and Sonora, Mexico south to Peru, usually in fresh water
- Fingers of second chela of adult male at most $0.6\times$ as long as palm. Rostrum almost straight 15
- 15. Fingers of second chela of adult male $0.5\text{--}0.6\times$ as long as palm. Carpus of first pereopod $2.0\times$ as long as chela. Weak spinules on pereopods 2–5
 ... *Macrobrachium rathbunae* Holthuis. Panama to Ecuador, fresh water (Holthuis 1952)
- Fingers of second chela of adult male $0.4\times$ as long as palm. Carpus of first pereopod $2.9\times$ as long as chela. Strong spinules on pereopods 2–5
 ... *Macrobrachium cocoense* Abele and Kim 1984. Isla del Coco, Costa Rica
- 16. Large chela of adult male without feltlike pubescence
 ... *Macrobrachium transandicum* Holthuis. Western Colombia, fresh water (Holthuis 1952)
- Large chela of adult male with distinct pubescence on lower surface of palm and fingers 17
- 17. Rostrum high with distinct unarmed region in ultimate half of upper margin
 *Macrobrachium gallus* Holthuis. Ecuador, fresh water (Holthuis 1952)

- Rostrum shallow, toothed to apex
..... *Macrobrachium occidentale* Holthuis. Sinaloa, Mexico to Panama,
usually in fresh water
- 18. (5) Branchiostegal spine absent. Second pereopods of adult male strongly
unequal in size and shape, spinulose. (Strictly fresh water)
..... *Cryphiops caementarius* (Molina). Peru and Chile, usually fresh water
(Holthuis 1952)
- Branchiostegal spine present. Second pereopods of adult male equal in
size and shape, not spinulose. (Fresh water or marine) 19
- 19. Mandible with palp 20
- Mandible without palp 25
- 20. Carpus of second pereopod distinctly shorter than chela.
..... *Palaemon ritteri* Holmes. San Diego, California to Ecuador
and Galapagos Islands
- Carpus of second pereopod equal to or longer than chela 21
- 21. Rostrum greatly exceeding length of scaphocerite, armed dorsally with
5-7 teeth 22
- Rostrum barely exceeding length of scaphocerite, armed dorsally with
8-9 teeth 23
- 22. Rostrum with 9-12 teeth on ventral surface. Second pereopods over-
reaching scaphocerite by less than length of chelae
..... *Palaemon gracilis* (Smith). Sinaloa, Mexico to Panama,
usually in fresh water
- Rostrum with 11-16 teeth on ventral surface. Second pereopods over-
reaching scaphocerite by length of chelae or more
..... *Palaemon hancocki* Holthuis. Colombia and Ecuador
- 23. Apex of rostrum elongate, without teeth. Second pereopods at most
reaching to end of scaphocerite
..... *Palaemon gladiator* Holthuis. Galapagos and Clipperton Islands
(Holthuis 1952)
- Apex of rostrum not elongate, with teeth. Second pereopods exceeding
end of scaphocerite 24
- 24. Three teeth on upper margin of carapace posterior to orbit, in line with
rostrum. Rostrum with dorsal subapical tooth
... *Palaemon macrodactylus* Rathbun. San Francisco Bay, Elkhorn Slough,
Malibu Lagoon and Los Angeles Harbor, California, introduced from
Korea or Japan (Chace and Abbott 1980; Standing 1981). (2)
- One tooth on dorsal surface of carapace in line with rostrum. Rostrum
without subapical teeth
..... *Palaemon peruanus* Holthuis. Coastal streams and rivers of Peru
(Holthuis 1952)
- 25. (19) Fused part of 2 rami of dorsal antennular flagellum distinctly longer
than free part of shorter ramus. (Rostrum with 6-8 dorsal teeth and 3-
4 ventral teeth)
..... *Palaemonetes paludosus* (Gibbes). Estuarine parts of Colorado River
drainage only. Widespread in eastern United States
- Fused part of 2 rami of dorsal antennular flagellum shorter than free
part of shorter ramus. (Rostrum with 8-13 dorsal teeth and 2-4 ventral
teeth) 26

26. Anterior margin of basal segment of antennular peduncle produced forward, overreaching anterolateral spine. Lower margin of rostrum not reaching level of antennular peduncle. Upper margin of rostrum with 8–11 teeth *Palaemonetes hiltoni* Schmitt
San Pedro, California to Gulf of California. (3)
- Anterior margin of basal segment of antennular peduncle not produced forward and not overreaching anterolateral spine. Lower margin of rostrum reaching level of antennular peduncle. Upper margin of rostrum with 11–13 teeth *Palaemonetes schmitti* Holthuis. Panama
27. (4) Third maxillipeds without exopods. (Inhabiting only subtidal zones) 28
- Third maxillipeds with exopods. (Inhabiting intertidal to subtidal zones) 33
28. Pleura of third–fifth abdominal segments ending in pointed, toothlike tips. Rostrum without dorsal teeth
..... *Pseudocoutierea elegans* Holthuis. Southern California to Colombia, Galapagos Islands
- Pleura of first–fourth abdominal segments rounded. Rostrum variable 29
29. Rostrum compressed, toothed 30
- Rostrum depressed, not toothed 31
30. Hepatic spine present, antennal spine absent. Rostrum not broadened over bases of eyestalks
..... *Waldola schmitti* Holthuis. Southwestern Mexico to Colombia (Holthuis 1951)
- Hepatic spine absent, antennal spine present. Rostrum broadened over bases of eyestalks
..... *Neopontonides dentiger* Holthuis. Sonora and Sinaloa, Mexico and Ecuador (Rios 1986)
31. Rostrum ending in distinct point, being triangular. Basal segment of antennular peduncle with strong spine at anterolateral angle
.... *Pontonides sympathes* de Ridder and Holthuis. Galapagos, commensal with *Antipatharia* (de Ridder and Holthuis 1979)
- Rostrum broadly truncate. Basal segment of antennular peduncle without strong spine at anterolateral angle 32
32. Anterior margin of rostrum with teeth. Scaphocerite with distinct final tooth. Second pereopods unequal
..... *Veleronia serratifrons* Holthuis. Ecuador, Galapagos Islands (Holthuis 1951). (4)
- Anterior margin of rostrum entire. Scaphocerite without or with indistinct final tooth. Second pereopods equal
.. *Veleronia laevifrons* Holthuis. Gulf of California, Isla Malpelo, Ecuador, Galapagos. Commensal with gorgonians (Abele 1975; Wicksten and Hendrickx 1985)
33. (27) Hepatic spine present 34
- Hepatic spine absent 44
34. Rostrum broad, deep. Body strongly depressed. Third pereopod with dactyl twisted distally
..... *Harpiliopsis depressa* (Stimpson). Gulf of California to Colombia,

- Galapagos Islands; also widespread in Indo-Pacific Region. Commensal with corals. (5)
- Rostrum narrow, slender. Body not depressed. Third pereopods with dactyl not twisted 35
 - 35. Second pereopods massive, dissimilar in size and shape. Rostrum barely exceeding eye, with at most one ventral tooth 36
 - Second pereopods more slender, similar in size and shape. Rostrum exceeding eye, with 0-3 ventral teeth 38
 - 36. Smaller second pereopod with dactyl short and high, almost semicircular. Rostrum with more than two dorsal teeth but without subterminal ventral tooth near apex
 ... *Periclimenaeus hancocki* Holthuis. Baja California and Guerrero, Mexico; Panama, Isla Malpelo, among sponges and corals (Rios 1986). (6)
 - Smaller second pereopod with dactyl elongate, never semicircular. Rostrum with at least two dorsal teeth, with or without subterminal ventral tooth 37
 - 37. Rostrum with subterminal ventral tooth. Merus of third pereopod with spinules
 *Periclimenaeus spinosus* Holthuis. Baja California, Costa Rica, among sponges or corals (Rios 1986)
 - Rostrum without subterminal ventral tooth. Merus of third pereopod without spinules
 *Periclimenaeus pacificus* Holthuis. Panama, Colombia, Galapagos (Holthuis 1951)
 - 38. Dorsal surface of rostrum straight to slightly concave, with 2-3 ventral teeth anterior to eye. Spine of scaphocerite exceeding distal end of blade 39
 - Rostrum arched over eye on dorsal surface, with 0-3 ventral teeth, all near apex. Spine of scaphocerite falling short of distal end of blade .. 40
 - 39. Second pereopods equal in size and shape. Rostrum straight
 *Palaemonella holmesi* (Nobili). Southern California to Ecuador
 - Second pereopods unequal in size and shape. Rostrum slightly concave
 *Palaemonella assymetrica* Holthuis. Galapagos (Holthuis 1951)
 - 40. With large, freely mobile hepatic spine. Second pereopods robust. (Dactyls of other pereopods simple. Rostrum with 7-10 dorsal teeth and 1 ventral tooth
 *Allopontonia iaini* Bruce. Western Pacific and Indian Ocean, Gulf of California. Commensal with sea urchins (Kerstitch 1987; Bruce 1987)
 - With smaller, immobile hepatic spine. Second pereopods more delicate. (Dactyls of other pereopods simple or biunguiculate. Rostrum with variable numbers of dorsal and ventral teeth 41
 - 41. Dactyls of last 3 pereopods simple 42
 - Dactyls of last 3 pereopods biunguiculate 43
 - 42. Third abdominal segment with pronounced hump. Lower margin of rostrum straight .. *Periclimenes lucasi* Chace. Gulf of California to Panama
 - Third abdominal segment without pronounced hump. Lower margin of rostrum convex *Periclimenes veleronis* Holthuis. Ecuador (Holthuis 1951)

43. Rostrum without ventral teeth. Chela of second pereopod stout
 . . . *Periclimenes soror* Nobili. Gulf of California to Panama, widespread in
 Indo-Pacific region, Red Sea (Bruce 1976; Wicksten and Hendrickx
 1985). (7)
- Rostrum with 1–2 ventral teeth. Chela of second pereopod slender . . .
 *Periclimenes infraspinis* (Rathbun). Southern California to
 Costa Rica and Galapagos Islands
44. (33) Blade of scaphocerite rudimentary. (Rostrum spiniform, without
 teeth. Commensal with sponges) 45
- Blade of scaphocerite well developed. (Rostrum and associations
 various) 48
45. Outer margin of uropodal exopod serrate
 *Typton serratus* Holthuis. Gulf of California, southwestern
 Mexico and Galapagos
- Outer margin of uropodal exopod entire 46
46. Dactyls of both second pereopods not semicircular, generally elongated.
 Carpus of second pereopod without lower spinules
 *Typton hephaestus* Holthuis. Southwestern Baja California, Gulf of
 California
- Dactyls of both second pereopods semicircular, upper margins strongly
 convex. Carpus of large second pereopod with spinules on lower border
 47
47. Antennal spine broad and tooth-shaped when seen from side. First pe-
 reopod slender, merus about equal in length to carpus
 *Typton tortugae* McClendon. Gulf of California, Bermuda, Florida,
 Virgin Islands (Chace 1972)
- Antennal spine clearly spiniform when seen from side. First pereopod
 robust, merus 1.4× length of carpus
 *Typton crosslandi* Bruce. Galapagos Islands (Bruce 1978)
48. Carapace with prominent dorsal teeth. (Commensal with antipatharians)
 *Chacella kerstitchi* (Wicksten). Gulf of California (Bruce 1986b). (8)
- Carapace without dorsal teeth. (Usually commensal with mollusks or
 ascidians, possibly sponges) 49
49. Rostrum compressed, with 3–4 dorsal teeth
 *Fennera chacei* Holthuis. Sinaloa, Mexico to Colombia, Galapagos,
 tropical Indo-West Pacific. Commensal with corals, *Pocillopora* spp.
 (Holthuis 1951; Patton 1966; Garth 1973). (9)
- Rostrum depressed, with at most two subapical teeth 50
50. Dorsal spines of telson small, inconspicuous 51
- Dorsal spines of telson large, well developed 52
51. Eyes, when extended laterally, reaching beyond antennal spines. Scapho-
 cerite without final tooth. Dactyls of fifth pereopods much stouter than
 those of third pereopods. Commensal with gastropods
 *Pontonia chimaera* Holthuis. Sonora, Mexico and Panama
- Eyes, when extended laterally, not reaching antennal spines of carapace.
 Scaphocerite with small final tooth. Dactyls of fifth pereopods similar to
 those of third pereopods. Commensal with pelecypods
 *Pontonia pinnae* Lockington. Gulf of California to Panama. (10)

52. Dactyls of last 3 pereopods broad, posterior margins distinctly convex
 (Usually commensal with pelecypods) *Pontonia margarita* Smith.
 Gulf of California to Colombia and Galapagos,
 North Carolina to Florida (Chace 1972)
- Dactyls of last 3 pereopods slender, posterior margins straight. (Commensal with pelecypods or not) 53
53. Dorsal spines of telson very long and slender, anterior pair reaching beyond base of posterior part. (Host not known)
 *Pontonia longispina* Holthuis. Gulf of California
- Dorsal spines of telson shorter, anterior pair reaching at most to middle of distance between both pairs 54
54. Antennal spine present. Commensal in *Pinna* spp.
 *Pontonia simplex* Holthuis. Gulf of California, southwestern Mexico
- Antennal spine absent. Commensal in ascidians or other species 55
55. Anterior pair of dorsal telson spines reaching to or beyond base of posterior pair
 *Pontonia californiensis* Lockington. Carmel, California to southern California, usually along offshore islands. (Holthuis 1951; Standing 1981)
- Anterior pair of dorsal telson spines not reaching base of posterior pair 56
56. Second pereopods dissimilar in size and shape
 *Pontonia spighti* Fujino. Costa Rica, commensal in ascidians (Fujino 1972)
- Second pereopods similar in size and shape
 *Pontonia pusilla* Holthuis. Panama and Ecuador (Holthuis 1951)

Notes

Numbers in parentheses after couplet numbers refer the reader to previous choices, enabling the user to "back up" in case of errors or questions.

1. The recent revision of the Palaemonidae by Bruce (1987) includes the genera *Gnathophyllum* and *Gnathophylloides* in the family as part of the subfamily Gnathophyllinae. Species of *Hymenocera* are placed in the subfamily Hymenocerinae.

2. *Palaemon macrodactylus* was taken at Malibu Lagoon, Los Angeles County, 1 November 1984, Don Galli, in brackish areas among algae and rocks, 3 specimens, AHF.

3. *Palaemonetes hiltoni* has not been reported from southern California since its description in 1921. The area where it was collected, the coast of San Pedro, has been extensively modified during construction of the port of Los Angeles. The species probably no longer regularly occurs along the coast of southern California.

4. De Ridder (1980) provided detailed information on population structure, host associations, morphology and coloration in the two species of *Velateria*.

5. For purposes of this paper, *Harpiliopsis depressa* (Stimpson) and *H. spinigera* (Ortmann) are considered to be synonyms. A. J. Bruce (pers. comm.) reports that the two species may be distinguished in life by the color pattern, but this information does not accompany the preserved specimens on which information on range is based.

6. *Periclimenaeus hancocki* was collected at Santa Lucia Bay, Guerrero, Mexico, 13 Sept. 1946, Carl Hubbs station H46-244, 2 specimens, AHF.

7. *Periclimenes soror* has been taken at two additional places in the Gulf of California: Isla Partida, off Isla Espiritu Santo, no date, B. Marquardt, 1 specimen; S. of "No Name Bay," SW end of Isla Espiritu Santo, 1 m, 19 Aug. 1965, A. Villalobos sta. D-34, 5 specimens, CAS.

8. *Chacella kerstitchi*, known previously only from the holotype, has been collected at Isla San Pedro Nolasco, Sonora, Mexico, 20 m, on *Antipathes galapagensis*, 21 June 1988, A. Kerstitch, 3 specimens, AHF.

9. *Fennera chacei* was taken at Marchena Island, Galapagos, 37 m, 3 Dec. 1934, *Velero III* station 311-35, 3 specimens, AHF.

10. See Campos-Gonzalez 1988 for details of host relationships in *P. pinnae* and *P. margarita*.

Literature Cited

- Abele, L. G. 1975. The macruran decapod Crustacea of Malpelo Island. *Smithson. Contr. Zool.*, 176:69-85.
- , and W. Kim. 1984. Notes on the freshwater shrimps of Isla del Coco with the description of *Macrobrachium cocoense*, new species. *Proc. Biol. Soc. Wash.*, 97(4):951-960.
- Bruce, A. J. 1976. *Periclimenes soror* Nobili, a pontoniine shrimp new to the American fauna, with observations on its Indo-West Pacific distribution. *Tethys*, 8(4):299-306.
- . 1978. *Typton crosslandi* sp. nov., a new pontoniine shrimp from the Galapagos Islands. *Crustaceana* 35(3):294-300.
- . 1986a. Observations on the family Gnathophyllidae Dana, 1852 (Crustacea: Decapoda). *J. Crust. Biol.*, 6(3):463-470.
- . 1986b. *Chacella*, a new palaemonid shrimp genus proposed for *Dasycaris kerstitchi* Wicksten, 1983 (Crustacea: Decapoda: Natantia). *J. Crust. Biol.*, 6(3):485-490.
- . 1987. The occurrence of an Indo-West Pacific shrimp, *Alloponotonia iaini* Bruce, in Mexican waters (Decapoda, Palaemonidae). *Crustaceana*, 53(3):306-307.
- Campos-Gonzalez, E. 1988. New molluscan hosts for two shrimps and two crabs on the coast of Baja California, with some remarks on distribution. *Veliger*, 30(4):384-386.
- Chace, F. A., Jr. 1972. The shrimps of the Smithsonian-Bredin Caribbean Expeditions, with a summary of the West Indian shallow-water species (Crustacea: Decapoda: Natantia). *Smithson. Contr. Zool.* 98., 179 pp.
- , and D. P. Abbott. 1980. Caridea: the shrimps. Pp. 567-576 in *Intertidal invertebrates of California*. (R. H. Morris, D. P. Abbott and E. C. Haderlie, eds.), Stanford Univ. Press, Stanford, 690 pp.
- de Ridder, C. 1980. Etude des populations de deux especes de *Veleronia* (Decapodes, Pontoniinae) associees aux Gorgonacea (Cnidaria, Octocorallia) de l'archipel des Galapagos. *Cahiers Biol. Mar.*, 21(2):181-199.
- de Ridder, C., and L. B. Holthuis. 1979. *Pontonides sympathes*, a new species of commensal shrimp (Crustacea, Decapoda, Pontoniinae) from Antipatharia in the Galapagos Islands. *Zool. Meded. Leiden*, 54(7):101-110.
- Fujino, T. 1972. A new pontoniid shrimp, *Pontonia spighti* sp. nov., associated with a newly described ascidian from the Pacific coast of Costa Rica (Decapoda, Natantia, Pontoniinae). *Publ. Seto Mar. Biol. Lab.*, 19(5):293-301.
- Garth, J. S. 1973. Decapod crustaceans inhabiting reef-building corals of Ceylon and the Maldiv Islands. *J. Mar. Biol. Ass. India*, 15:195-212.
- Holthuis, L. B. 1951. A general revision of the Palaemonidae (Crustacea Decapoda Natantia) of the Americas. I. The subfamilies Euryrhynchinae and Pontoniinae. *Occ. Papers Allan Hancock Found* 11, 332 pp.
- . 1952. A general revision of the Palaemonidae (Crustacea Decapoda Natantia) of the Americas. II. The subfamily Palaemoniinae. *Occ. Papers Allan Hancock Found*. 12, 396 pp.
- Kerstitch, A. 1987. Sea feature. *Sea Frontiers* 33(2), back cover.

- McCourt, R. M., and D. A. Thomson. 1984. Cleaning behavior of the juvenile Panamic sergeant major, *Abudefduftroschelii* (Gill), with a resume of cleaning associations in the Gulf of California and adjacent waters. *Calif. Fish & Game*, 70(45):234-239.
- Mortensen, T. 1918. Papers from Dr. Th. Mortensen's Pacific expedition 1914-16. I. Observations on protective adaptations and habits, mainly in marine animals. *Vidensk. Meddr. Dansk Naturh. Foren.*, 69:57-96.
- Patton, W. K. 1966. Decapod Crustacea commensal with Queensland branching corals. *Crustaceana*, 10:271-295.
- Reynolds, W. W. 1977. Substrate feeders and facultative cleaners: cleaning behaviour in some Gulf of California marine animals. *Anim. Behav.*, 25:1063.
- Rios, R. 1986. Caridean shrimps of the Gulf of California. V. New records of species belonging to the subfamily Pontoniinae (Crustacea: Decapoda: Palaemonidae). *Proc. Biol. Soc. Wash.*, 99(3): 429-434.
- Standing, J. D. 1981. Occurrences of shrimps (Natantia: Penaeidae and Caridea) in central California and Oregon. *Proc. Biol. Soc. Wash.*, 94(3):774-786.
- Villalobos, F. A. 1966. Estudio de los Palaemonidae de Mexico. 1. *Macrobrachium acanthochirus* n. sp., del suroeste de Mexico. *Anales del Instituto de Biologia, Universidad de Mexico*, 37(1-2):167-173.
- Wicksten, M. K. 1983. A monograph on the shallow-water caridean shrimps of the Gulf of California, Mexico. *Allan Hancock Monogr. Mar. Biol.* 13, 59 pp.
- , and M. E. Hendrickx. 1985. New records of caridean shrimps in the Gulf of California, Mexico. *Proc. Biol. Soc. Wash.*, 98(3):571-573.

Accepted for publication 7 September 1988.

Late Quaternary Sciuridae from Kokoweef Cave, San Bernardino County, California

H. Thomas Goodwin¹ and Robert E. Reynolds²

¹*Museum of Natural History, University of Kansas,
Lawrence, Kansas 66045*

²*San Bernardino County Museum, 2024 Orange Tree Lane,
Redlands, California 92374*

Abstract.—Kokoweef Cave is located at about 1770 m elevation in the Ivanpah Mountains, northeastern San Bernardino County, California. Fossils were recovered from a 9-m-thick sedimentary sequence in the cave that may span several thousand years of latest Pleistocene and early Holocene time. We examined nearly 1500 specimens of the rodent family Sciuridae. Nine taxa, including five extralimitals, were identified. Dominant species (*Marmota flaviventris*, *Spermophilus townsendii*, *S. lateralis*) are extralimitals found today in the Great Basin. Overall, taxonomic and ecologic stability characterized the local late Quaternary sciurid faunal record. Significantly, extralimitals seem to persist through the Pleistocene-Holocene transition.

In the early 1970s, the San Bernardino County Museum (SBCM) was contacted about fossils discovered during private gold mining activity in Kokoweef Cave. The cave is located on Kokoweef Peak in the montane eastern Mojave Desert, northeastern San Bernardino County, California (Fig. 1). Crews from the SBCM, with the cooperation of the miners, were able to salvage hundred of thousands of specimens from a 9-m-thick sedimentary sequence in the cave. The fossil assemblage includes over 50 vertebrate species and as such is the most diverse late Quaternary vertebrate assemblage yet discovered in the Mojave Desert. However, only a preliminary list of the mammals (Kurten and Anderson 1980; Harris 1985) and a brief systematic treatment of the lacertilid reptiles (Norell 1986) have been published.

In this paper we provide a brief published description of the geologic and temporal context of the Kokoweef Cave assemblage. We also report on the sciurid rodents (Family Sciuridae, squirrels and allies), a common and diverse group in the Kokoweef Cave assemblage, and discuss their local late Quaternary history as recorded in the sedimentary sequence. This study is the first to examine a group through the entire Kokoweef Cave sequence.

Geologic and Temporal Context

Kokoweef Cave is a solution cavity in Paleozoic limestones located at 35°25'N, 115°30'W on 1840-m-high Kokoweef Peak in the Ivanpah Mountains (Fig. 1). The 2 m by 1 m natural entrance, situated at about 1770 m on the northwest slope of the peak, leads into a horizontally-elongate, southeast-trending upper chamber with a sloping, rock-strew floor. About 21 m from the entrance, the

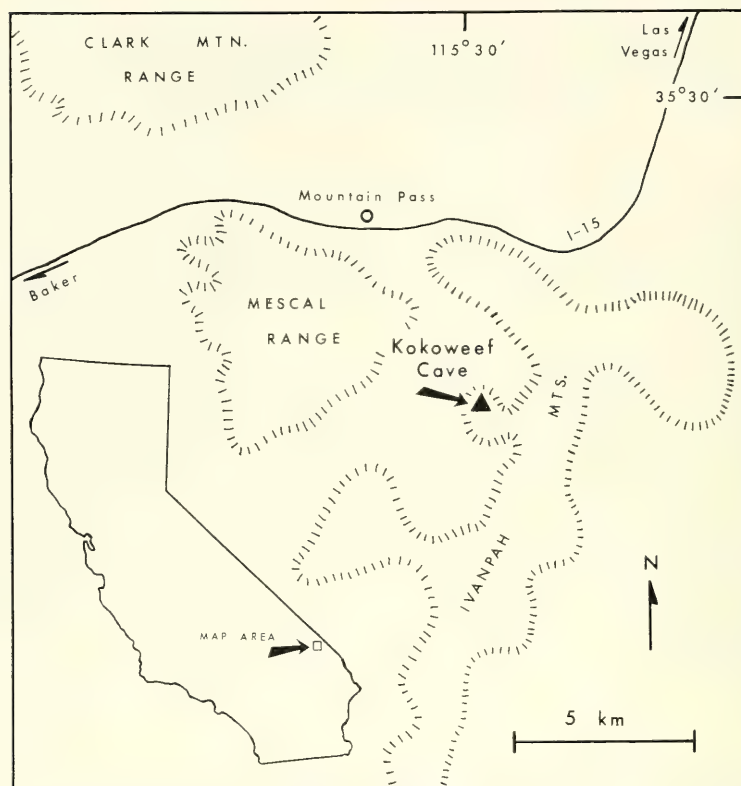


Fig. 1. Map showing the location of Kokoweef Cave within the Ivanpah Mountains area of south-eastern California. The hachured lines give the approximate boundaries of mountainous terrain.

chamber angles towards the southwest; and 15 m after the change in direction, this chamber abruptly gives way to a steep-walled, 25-m-deep lower chamber, which was partly filled with rubble-strewn, poorly-stratified sands prior to excavation. Most fossil specimens were recovered from the sands of the lower chamber. These sediments, which would have been introduced from the upper chamber over the lip of the northeast wall of the lower chamber, probably dipped toward the southwest.

The fossil accumulation probably resulted from 1) animals which accidentally fell into the lower chamber and 2) the activity of biological collectors that frequented the upper chamber. Among the latter, woodrats (*Neotoma*), mammalian carnivores (e.g., *Canis*, *Vulpes*, *Lynx*), and predatory birds (e.g., *Falco*, *Buteo*, *Gymnogyps*, and owls) were probably involved; all have been identified in preliminary study of the Kokoweef Cave assemblage.

The amount of time recorded in the poorly-stratified Kokoweef Cave depositional sequence is unknown, but we feel that at least several thousand years may be represented. One radiocarbon date, obtained on charcoal from about 6 m above the base of the sequence (level 20.5 ft), is early Holocene in age (9830 ± 150 yr. BP; Beta-2155). It therefore seems likely that the entire 9-m-thick deposit spans the Pleistocene-Holocene boundary. However, most fossils were recovered below

this dated level (Table 1) and are probably latest Pleistocene in age. Attempts to date lower levels in the cave were not successful. A spurious determination of 590 ± 120 yr. BP (AA-1890) was obtained by accelerator mass spectrometric analysis of a very small carbon sample from low in the sequence (level 31.5 ft). Downward movement of young carbon may have occurred during excavation or as the result of water movement through the sands.

There are three taphonomic factors which might obscure resolution of faunal history from the Kokoweef Cave sedimentary sequence. First, small landslides from the upper chamber could periodically deposit "packages" of sediment in the lower chamber. Each "package" would represent a time-averaged unit of unknown duration. Second, specimens may have been trapped in woodrat middens or rock litter in the upper cave before falling into the lower chamber. Because some specimens would remain in the upper chamber longer than others, temporal mixing of individuals would occur. This temporal mixing might have the effect of making last occurrences appear too young. Third, collection of fossiliferous matrix from arbitrary stratigraphic intervals (see "Methods" section) might sample significantly diachronous levels in dipping cave sediments. However, most of the Kokoweef fossils were recovered from the west wall of the chamber which would have been on the down side of the dip, reducing the problem of diachroneity. We acknowledge these potential taphonomic biases but believe that the sedimentary sequence, as a whole, preserves a relatively accurate faunal history.

Methods

A few fossils were obtained from a packrat midden in the upper chamber but most specimens were recovered from sands in the lower chamber (Table 1). Because the fossiliferous sands were poorly stratified, fossils were collected from arbitrary 1 ft vertical increments in the sedimentary sequence. Collection began at the 11 ft level and continued through the 40 ft level; measurements indicate distance below a mining trestle constructed about midway down the lower chamber. Because original measurements were recorded in English units, they are used here to minimize awkward conversions to metric units. Bulk matrix samples were collected at each increment, washed through 8- and 20-mesh-to-the-inch screens, and sorted. Specimens were deposited in the collections of the SBCM.

Nearly 1500 specimens of dental (less incisors, P³s), mandibular, and skull material of the family Sciuridae were examined. No post-cranial material was studied. Fossils were compared with Recent specimens in the SBCM and Loma Linda University comparative collections and identified on criteria outlined by Bryant (1945). Additional comparisons were made with specimens from the Los Angeles County Museum, University of California Museum of Vertebrate Zoology, and University of Kansas Museum of Natural History. Minimum number of individuals (MNI) for each species was calculated for the packrat midden of the upper chamber and the following intervals of the lower chamber (in feet): 11-16; 16-22; 23-24; 24-25; 25-26; 26-28; 28-29; 29-30; 30-32; 32-36; 36-40. Frequencies (n) for each taxon, and MNI for species, are given in Table 1.

To evaluate the significance of frequency changes through the sequence, a X^2 test was done for the three dominant species (*Marmota flaviventris*, *Spermophilus townsendii*, *S. lateralis*) using MNI as a measure of frequency. Because of small sample sizes, fossils from sediments in the lower chamber were further grouped

Table 1. Occurrence of sciurid species in Kokoweef Cave sediments.

Sciurid taxa	PM	Occurrence in cave (intervals in ft)																UN	Total
		11-16	16-22	22-23	23-24	24-25	25-26	26-28	28-29	29-30	30-32	32-36	36-40						
<i>Tamias minimus</i>		1/1	14/2	22/3	5/2	3/1	5/1	7/3	2/1	3/2	3/1	3/1	3/1	36-40	65/17				
<i>Tamias</i> sp. intermediate		1/1	1/1	10/2	5/2	7/2	5/2	9/2	7/2	3/2	4/1	3/1	3/1	60/20					
<i>Tamias</i> sp. large		1/1	2/1	10/2	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	17/8					
<i>Tamias</i> spp.			15/-	17/-	6/-	8/-	18/-	10/-	8/-	8/-	8/-	1/-	1/-	91/-					
<i>Marmota flaviventris</i>	5/2	4/1	6/2	32/5	68/10	29/4	41/4	28/3	46/4	38/5	20/3	36/3	8/1	26/-	387/47				
cf <i>Amnospermophilus leucurus</i>		7/3	1/1	2/1	3/2	3/1	2/1	8/2	2/1	2/2	1/1	1/1	1/-	33/16					
<i>Spermophilus townsendii</i>		1/1	1/1	46/5	121/12	41/4	34/6	37/5	37/5	18/3	35/4	22/3	11/2	4/-	408/51				
cf <i>S. variegatus</i>	1/1		2/1	1/1	2/1			5/1	4/2	1/1	3/1	1/1	2/1	5/-	27/11				
<i>S. (Xerospermophilus)</i> sp.								1/1						1/1					
<i>S. lateralis</i>		1/1	3/1	48/7	71/9	11/2	10/1	4/1	20/3	10/2	8/3	3/1	1/1	3/-	193/32				
<i>Spermophilus</i> spp.		1/-	32/-	64/-	17/-	27/-	14/-	11/-	22/-	21/-	4/-	1/-	1/-	215/-					
Totals	6/3	14/7	15/8	203/24	382/41	122/17	131/16	129/16	142/20	108/16	95/17	79/10	31/8	40/-	1497/203				

Frequencies are n/MNI. PM = packrat midden of the upper chamber; UN = exact placement in sediments of lower chamber unknown.

Frequencies are n/MNI. PM = packrat midden of the upper chamber; UN = exact placement in sediments of lower chamber unknown.

(11–23; 23–24; 24–26; 26–29; 29–32; 32–40) in order to fulfill a statistical convention of the X^2 test that not more than 20% of expected frequencies be less than 5. With $df = 5$, and $P < .05$, the critical X^2 value is 11.07; values greater than this would indicate a statistically significant change for a species through the sequence.

Measurements of fossils and some Recent *Tamias* specimens were made with an ocular micrometer. Measurements of other Recent *Tamias* specimens were made with a stage measuring microscope.

Systematic Accounts

The taxonomy that follows is that of Hall (1981), with one exception. We follow Levenson et al. (1985), not Hall (1981), in placing western chipmunks within the genus *Tamias*.

Because of the large number of specimens considered in this study, we do not list specimens and catalogue numbers individually in the systematic accounts. For each taxon, all specimens are summarized by element. Catalogue numbers are given separately and are grouped where possible to save space.

Family SCIURIDAE

Genus *Tamias* Illiger, 1811

Tamias minimus Bachman, 1839 — Least chipmunk

Referred material. — 4 R, 5 L maxillae; 2 L P⁴; 8 R, 13 L M¹⁻²; 4 R, 3 L M³; 5 R, 4 L dentaries; 8 R, L M₁₋₂; 5 R, 3 L M₃ (SBCM L 1808-139, -147-158, -300-314, -519-523, -619-621, -722-726, -836-839, -941-942, -1040-1042, -1145-1146).

The observed size range of fossil chipmunk specimens in the assemblage (Fig. 2) probably indicates the presence of at least three species. To facilitate identifications, size comparisons were made with nine of the species that now occur within the Great Basin, Sierra Nevada, or Mojave Desert (Fig. 2). Qualitative dental characters were not found to be useful in the identification of these species.

Small specimens in the Kokoweef Cave assemblage are most comparable in size to *Tamias minimus* (Fig. 2), the smallest extant chipmunk in the Great Basin, and almost certainly represent this extralimital species. The species is present through most of the Kokoweef Cave sequence (Table 1). Today, the range of *T. minimus* extends across Canada and down into the western United States. The nearest extant population occurs over 200 km north-northwest of Kokoweef Cave in the southern Great Basin (Hall 1981:345). Late Pleistocene records for the taxon are known from the Great Basin (Harris 1985:209), but this is the first documented occurrence in the eastern Mojave Desert.

Tamias sp. intermediate

Referred material. — Palate with R and L maxillae; 2 R, L maxillae; R, 2 L P⁴; 8 R, 11 L M¹⁻²; 5 R, 2 L M³; 7 R, 3 L dentaries; 10 R, 5 L M₁₋₂; R, L M₃ (SBCM L 1808-109, -118, -159-164, -315-319, -524-529, -622-625, -727-732, -797, -840-844, -943-946, -1043-1044, -1106-1108, -1147-1149).

Many of the Kokoweef Cave specimens are larger than *Tamias minimus* and represent an intermediate-sized species. These specimens are comparable in size

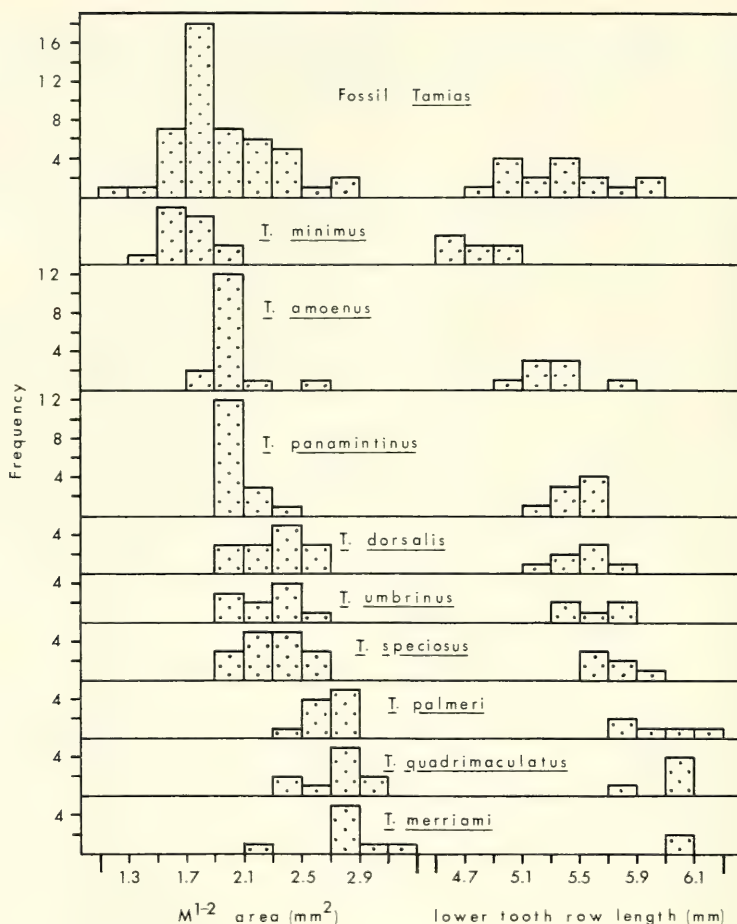


Fig. 2. Histograms giving frequency per size class for selected elements (M^{1-2} , dentaries) of fossil and some Recent chipmunks (*Tamias*). Marginal cases are counted in the size class to the right. M^{1-2} area represents length $\times$ width and does not equal exact area.

(Fig. 2) to the locally-extant *T. panamintinus*, the Panamint chipmunk, which inhabits pinyon-juniper woodlands of the high-elevation eastern Mojave and southwestern Great Basin deserts (Hall 1981:363). However, several other similar-sized species (*T. amoenus*, *T. dorsalis*, *T. umbrinus*, *T. speciosus*; Fig. 2) now occur in the Great Basin or Sierra Nevada and might have occurred at Kokoweef Cave in the latest Pleistocene. Thus, no specific identification is proposed. The intermediate-sized chipmunk is present throughout the depositional sequence (Table 1).

Tamias sp. large

Referred material.—2 R, L maxillae; R M^{1-2} ; L M^3 ; 2 R, L dentaries; R P_4 ; 4 R, L M_{1-2} ; R, 2 L M_3 (SBCM L 1808-122, -168-169, -320-329, -530, -626, -1045, -1150).

These large specimens fall within the size range of three of the Recent species

we considered: *T. palmeri*, *T. quadrimaculatus*, and *T. merriami* (Fig. 2). No large-sized chipmunk occurs in the Kokoweef Cave area today, but *T. palmeri* occurs in the Spring Mountains of southern Nevada (Hall 1981:365), only 50 km to the north-northeast. *Tamias merriami* now occurs in California mountain ranges west of the Great Basin, Mojave, and Sonoran deserts (Hall 1981:355), but it is possible that it ranged into the Great Basin and montane eastern Mojave Desert during the latest Pleistocene. Recent work supporting a possible relationship between *T. merriami* and *T. palmeri* (Levenson et al. 1985) is consistent with this hypothesis. *Tamias quadrimaculatus* presently has a very limited distribution in one area of the Sierra Nevada (Hall 1981:361).

The large-sized Kokoweef Cave chipmunk is not as abundant in the assemblage as the two smaller-sized species. However, it is present from levels throughout the sequence (Table 1). Whatever the specific identity of this chipmunk, it no longer occurs at Kokoweef Cave.

Tamias spp.

Referred material.—3 R, 4 L maxillae; 8 R, L P⁴; 7 R, 5 L M¹⁻²; R, 2 L M³; 7 R, 8 L dentaries; 3 R, 4 L P₄; 15 R, 14 L M₁₋₂; 4 R, 5 L M₃ (SBCM L 1808-170-179, -330-342, -531-536, -627-628, -630-634, -733-743, -798-801, -845-847, -849-852, -947-953, -1077, -1109-1111, -1132-1133, -1151).

These specimens probably represent one of the above species, but size overlap between species makes it impossible to assign all specimens to the specific level.

Genus *Marmota* Blumenbach, 1779

Marmota flaviventris (Audubon and Bachman), 1841—Yellow-bellied marmot

Referred material.—9 partial to complete skulls; 2 R, 6 L premaxillae; 26 R, 17 L maxillae; 7 R, 8 L dP⁴; 14 R, 17 L P⁴; 43 R, 33 L M¹⁻²; 20 R, 12 L M³; 24 R, 28 L dentaries; 3 R, 6 L dP₄; 11 R, 12 L P₄; 30 R, 36 L M₁₋₂; 12 R, 11 L M₃ (SBCM L 1808-96-100, -102-106, -119, -125-126, -128-137, -140-143, -180-200, -202-208, -292-299, -343-358, -360-394, -537-539, -540-555, -559-562, -635-647, -649-662, -744-747, -749, -751-756, -802-808, -810-816, -854-861, -866-878, -880-885, -954, -957-963, -965-970, -1004-1011, -1046-1054, -1078, -1081-1083, -1085-1088, -1090-1094, -1112-1116, -1129-1131, -1134, -1153-1156, -1162-1165, -1171-1172).

Marmota flaviventris can be readily identified on the basis of its large size. Fossil specimens are similar in size to modern specimens that we examined. The species occurs throughout the Kokoweef Cave sequence and was a dominant taxon at most levels. A χ^2 test ($\chi^2 = .375$) indicates that there was no significant fluctuation in its relative frequency through the sequence.

Today, this species ranges across the Rocky Mountains, montane Great Basin, and down the Sierra Nevada (Hall 1981:373). Extant populations nearest to Kokoweef Cave are in the southern Sierra Nevada, about 250 km to the west. However, during the latest Pleistocene this species occurred in highlands well south of its present range (Frase and Hoffman 1980; Harris 1985:195; Grayson 1987) and at elevations lower than it does today (Grayson 1987). Its presence in the Kokoweef Cave assemblage is thus not surprising.

Genus *Ammospermophilus* Merriam, 1892*Ammospermophilus* cf. *A. leucurus* (Merriam), 1889—

White-tailed antelope squirrel

Referred material.—Skull; 3 R maxillae; R dP⁴; 3 L P⁴; 5 R, 4 L M¹⁻²; 2 R M³; L dentary; R, 4 L M₁₋₂; 4 R, 4 L M₃ (SBCM L 1808-110-114, -116, -121, -209-210, -396-397, -565-567, -663-664, -757-763, -888-889, -972, -1055, -1177, -1173).

Identification of the genus *Ammospermophilus* in the Kokoweef Cave assemblage is based on the small size of specimens, the incomplete metaloph and broad protocone on P⁴ through M², and numerous features of a nearly complete skull. Significant size overlap and morphological similarity among the four extant species in the genus make it difficult to discriminate among these species on the basis of limited osteological evidence.

Based primarily on zoogeographic evidence, we refer fossil specimens to *Ammospermophilus leucurus*, currently the dominant sciurid at Kokoweef Cave. This species is comparable in size and morphology to the fossil specimens and is the one now found in the Mojave Desert, Great Basin, and on the Colorado Plateau (Hall 1981:379). *Ammospermophilus harrisii* is now present in the deserts of Arizona, south and east of the Colorado River and south of the Colorado Plateau (Hall 1981:378), and extant populations occur within 100 km of Kokoweef Cave. However, this region is an unlikely source for latest Pleistocene colonization of the Kokoweef Cave area. As discussed below (see "Discussion" section), the dominant sciurids in the Kokoweef Cave assemblage now occur at higher latitudes and elevations in the Great Basin. *Ammospermophilus nelsoni*, now restricted to the San Joaquin Valley west of the Sierra Nevada (Hall 1981:256), and *A. interpres*, now ranging south and east of central New Mexico (Hall 1981:255), are even less likely to have occurred at Kokoweef Cave.

Ammospermophilus leucurus is present in low frequencies throughout the sequence but appears to increase in relative frequency in the youngest intervals. This species evidently occupied much of its present range during the late Pleistocene. In the Great Basin, as at Kokoweef Cave, it has been found associated with montane taxa (Mead et al. 1982).

Genus *Spermophilus* Cuvier, 1825*Spermophilus* (*Spermophilus*) *townsendii* Bachman, 1839—

Townsend's ground squirrel

Referred material.—Skull; 23 R, 18 L maxillae; R, 4 L dP⁴; 12 R, 16 L P⁴; 49 R, 50 L M¹⁻²; 10 R, 14 L M³; 12 R, 20 L dentaries; R dP₄; 14 R, 18 L P₄; 58 R, 55 L M₁₋₂; 19 R, 13 L M₃ (SBCM L 1808-117, -124, -138, -211-222, -224-234, -398-443, -568-591, -665-673, -675-694, -764-781, -818-824, -890-906, -973-979, -1012-1018, -1020-1027, -1056-1061, -1095-1102, -1118-1124, -1135-1137, -1139-1144, -1157-1159, -1166-1167, -1174-1175).

Features that unite these specimens with the ground squirrel subgenus *Spermophilus* (*Spermophilus*) include tooth crown height, triangular occlusal shape and complete metaloph of P⁴ through M², and dorsally projecting coronoid process of the dentary. Specific identification of *S. townsendii* is based on size of the specimens. Two other species in the subgenus, *S. richardsonii* and *S. beldingi*,

now co-occur with *S. townsendii* in northern Nevada, but both are much larger than the fossil specimens. As noted in the account of *S. lateralis*, M^3 s and lower teeth of *S. townsendii* were sometimes difficult to distinguish from those of *S. lateralis*.

This ground squirrel is very abundant in the fossil assemblage ($N = 408$, $MNI = 51$) and is a dominant species throughout the sequence. However, the X^2 test ($X^2 = 1.74$) shows that there is no significant fluctuation in relative frequency of the species through the sequence. It is presently widespread through the desert-scrub and pygmy-conifer communities of the Great Basin (Hall 1946) but does not range into the Mojave Desert; the closest extant population is about 150 km north-northeast of Kokoweef Cave in southern Nevada (Hall 1981:383). As a fossil, it is known from several late Pleistocene localities in the Great Basin (Harris 1985:207), but this is the first record from the eastern Mojave Desert.

Spermophilus (Otospermophilus)

cf. *S. variegatus* (Erxleben), 1777—Rock squirrel

Referred material.—R, L premaxilla; L P^4 ; L dP^4 ; 3 R, 3 L M^{1-2} ; 3 L M^3 ; 2 R, 2 L dentaries; R L P_4 ; 2 R, 2 L M_{1-2} ; 2 R, L M_3 (SBCM L 1808-101, -107, -235-236, -444, -592-593, -782-783, -825-827, -907-909, -988, -1028, -1062-1063, -1103, -1168-1169, -1176-1178).

Based on large size, the incomplete metaloph on P^4 through M^2 , and other dental details, these specimens certainly represent the ground squirrel subgenus *Spermophilus (Otospermophilus)*. We refer them to *S. variegatus*, the otospermophile extant in the Kokoweef Cave vicinity. However, *S. variegatus* is very similar in size and morphology to *S. beecheyi*, the other California otospermophile which now occurs west of the Mojave Desert. We consider it unlikely that the recovered specimens represent the latter species. Despite its present local abundance, *S. variegatus* is found only at low frequencies in the assemblage, although it occurs at intervals throughout the sequence. It is known as a fossil from a number of localities, mostly within its modern range (Harris 1985:207).

Spermophilus (Xerospermophilus) sp.

Referred material.—R M^{1-2} (SBCM L 1808-828).

This specimen is characterized by an incomplete metaloph and a relatively broad protocone. This combination of characters is exhibited by *Ammospermophilus*, *Spermophilus (Otospermophilus)*, and *S. (Xerospermophilus)*. However, this specimen, measuring 1.8 mm by 2.4 mm, is much smaller than *S. (Otospermophilus)* and is larger than fossil and Recent specimens of *Ammospermophilus* that we have examined. We refer it to the subgenus *S. (Xerospermophilus)*, which includes *S. tereticaudus*, presently found in sandy habitats a few km from Kokoweef Cave (Johnson et al. 1948), and *S. mohavensis*, now restricted to the western Mojave Desert (Hall 1981:405). We have not attempted to specifically identify this specimen because it falls within the range of size overlap between the two extant species.

The specimen was found in the 27–28 ft interval and probably indicates the presence of xerospermophiles in the eastern Mojave Desert during the late Pleistocene. Otherwise, this subgenus is known as a fossil only from a single woodrat midden in the Sonoran Desert dated at about 8000 yr. BP (Mead et al. 1983).

Spermophilus (Callospermophilus) lateralis (Say), 1823—
Golden-mantled ground squirrel

Referred material.—12 R, 6 L maxillae; L dP⁴; 7 R, 5 L P⁴; 19 R, 31 L M¹⁻²; 4 R, 5 L M³; 12 R, 12 L dentaries; R, 2 L dP⁴; 5 R, 8 L P⁴; 18 R, 29 L M₁₋₂; 9 R, 7 L M₃ (SBCM L 1808-115, -144-146, -237-245, -247-270, -445-471, -473-484, -594-603, -695-703, -784-785, -829-830, -910-921, -940, -980-987, -1029-1030, -1064-1066, -1125-1126, -1170, -1179, -1181).

Spermophilus lateralis is similar in size to *S. townsendii*. However, it differs from the latter in the more quadrate occlusal outline of upper teeth, lesser tooth crown height, less triangular infraorbital foramen, more posteriorly projecting coronoid process of the dentary, and various other features. The M³s and lower cheek teeth of these species can sometimes be confused. However, *S. lateralis* tends to exhibit a shorter M³ and M₃ and more elongate M₁ and M₂.

Spermophilus lateralis is present through the Kokoweef Cave sequence (Table 1), but it is relatively more frequent in the younger levels. However, the X² test (X² = 3.94) indicates that there is no significant change in frequency through the sequence. The species is now widespread in pine and fir forests of the montane West but does not occur in the Kokoweef Cave vicinity. The closest extant population is about 50 km north-northeast of Kokoweef Cave in the Spring Mountains of southern Nevada (Hall 1981:409). As a fossil, the species is known from a number of late Pleistocene localities, some south of its modern range (Harris 1985:207; Grayson 1987).

Spermophilus spp.

Referred material.—7 R, 7 L maxillae; R, L d²P⁴; 9 R, 7 L P⁴; 8 R, 4 L M¹⁻²; 20 R, 22 L M³; 10 R, 21 L dentaries; R, 3 L P⁴; 29 R, 34 L M₁₋₂; 14 R, 17 L M₃ (SBCM L 1808-108, -123, -271-288, -485-510, -604, -606-617, -704-719, -786, -788-794, -831-835, -922-925, -927-931, -919-990, -993-997, -999-1001, -1032-1035, -1037-1038, -1068-1076, -1104-1105, -1127-1128, -1160).

These specimens could not be identified to the specific level. Most of these probably represent *Spermophilus townsendii* or *S. lateralis*.

Discussion

The Kokoweef Cave sciurid assemblage differs significantly in composition and diversity from the modern desert-adapted sciurid fauna of the Ivanpah Mountains (Johnson et al. 1948). However, it exhibits strong zoogeographic similarity to the modern sciurid fauna of the Great Basin. Six of seven taxa identified to species or species group now occur in the Great Basin. Of these, the four taxa most abundant in the assemblage (*Marmota flaviventris*, *Spermophilus townsendii*, *Spermophilus lateralis*, *Tamias minimus*) no longer occur in the Mojave Desert. *Spermophilus (Xerospermophilus)* is the only taxon in the assemblage (excluding the two chipmunk species of unknown affinity) that today occurs in the Mojave Desert but not within the Great Basin. This taxon evidently occurred in the eastern Mojave Desert during the latest Pleistocene but probably did not inhabit the immediate vicinity of Kokoweef Cave.

The occurrence of "boreal" sciurids (sensu Brown 1971; *Marmota flaviventris*, *Spermophilus lateralis*) in the Kokoweef Cave assemblage is not surprising. Many late Pleistocene sites at relatively low elevations and southerly latitudes have

yielded similar "boreal" forms (Harris 1985; Grayson 1987). As Grayson (1987) has shown, these records provide support for Brown's (1971, 1978) hypothesis that "boreal" mammal ranges, often disjunct today, were continuous in the Pleistocene and have since been disrupted by the elimination of low elevation populations.

The strong Great Basin aspect to the sciurid fauna suggests a local late Wisconsin climate with similarities to the present climate to the north—cool, dry, with a winter precipitation regime. This is essentially the hypothesis of Spaulding and Graumlich (1986) based on paleobotanical data. However, the basically modern lacertilid reptile assemblage from Kokoweef Cave (Norell 1986) may constrain cool temperature estimates. Whatever the climate, the area was more heavily wooded than today. Direct evidence is provided by the Clark Mountain woodrat midden record of montane conifer woodlands a few km north of Kokoweef Cave (Mehringer and Ferguson 1969).

Local sciurid faunal history recorded in the sedimentary sequence does not indicate significant taxonomic or ecologic change. Most taxa occur through the sequence, and apparent frequency fluctuations are not statistically significant. However, MNI as an estimate of frequency over-represents the rare taxa, under-represents common taxa, and thus may mask real fluctuations in the Kokoweef Cave record. This may be the case with *Spermophilus lateralis*, which exhibits low frequencies towards the base of the sequence and high frequencies in the 22–24 ft interval. The general stasis in the relative abundance of most sciurid taxa through the sequence seems to be consistent with the general stability in vegetation and inferred climate in the Southwest through the late Wisconsin to about 11,000 yr. BP (Van Devender et al. 1987).

Of special interest is the presence of extralimital sciurids at or well above the 20.5 ft level, dated at about 9800 yr. BP. We recognize a potential time resolution problem. As previously discussed, these fossils may represent late Pleistocene specimens caught in the upper cave before introduction into the sediments of the lower chamber. However, 17 specimens of extralimital taxa were recovered from the 11–22 ft interval, and we believe that at least some of these specimens represent early Holocene populations. Evidently, terminal Pleistocene climatic change, centering around 11,000 yr. BP in the arid Southwest (Van Devender et al. 1987), did not eliminate habitats suitable for extralimital sciurids in the Kokoweef Cave vicinity. Extinction of these taxa may have resulted from further habitat disruption as climate attained essentially modern aspect by about 8500 yr. BP (Van Devender et al. 1987).

Acknowledgments

We thank the Concave Mining Company which allowed SBCM access to the Kokoweef Cave deposits; the Geoscience Research Institute and Department of Biology, Loma Linda University, which provided funding for this study; J. Reynolds, G. T. Jefferson, and an anonymous reviewer who critically read and improved earlier versions of this manuscript; and L. R. Brand who provided guidance through much of this project.

Literature Cited

- Brown, J. H. 1971. Mammals on mountaintops: nonequilibrium insular biogeography. *Amer. Nat.*, 105:467–477.

- . 1978. The theory of insular biogeography and the distribution of boreal birds and mammals. Pp. 209–277 in *Intermontane biogeography: a symposium*. (K. T. Harper and J. L. Reveal, eds.), *Great Basin Naturalist Mem.*, 2:1–268.
- Bryant, M. D. 1945. Phylogeny of Nearctic Sciuridae. *Amer. Midland Nat.*, 33:257–390.
- Frase, B. A., and R. S. Hoffman. 1980. *Marmota flaviventris*. *Mamm. Species*, 135:1–8.
- Grayson, D. K. 1987. The biogeographic history of small mammals in the Great Basin: observations on the last 20,000 years. *J. Mamm.*, 68:359–375.
- Hall, E. R. 1946. *Mammals of Nevada*. Univ. California Press, 710 pp.
- . 1981. *The mammals of North America*. Vol. 1. Second ed. John Wiley & Sons, 600 + 90 pp.
- Harris, A. H. 1985. Late Pleistocene vertebrate paleoecology of the West. Univ. Texas Press, 293 pp.
- Johnson, D. H., M. D. Bryant, and A. H. Miller. 1948. Vertebrate animals of the Providence Mountains area of California. *Univ. California Publ. Zool.*, 48:221–376.
- Kurten, B., and E. Anderson. 1980. *Pleistocene mammals of North America*. Columbia Univ. Press, xvii + 442 pp.
- Levenson, H., R. S. Hoffman, C. F. Nadler, L. Deutsch, and S. D. Freeman. 1985. Systematics of the Holarctic chipmunks (*Tamias*). *J. Mamm.*, 66:219–242.
- Mead, J. I., R. S. Thompson, and T. R. Van Devender. 1982. Late Wisconsinan and Holocene fauna from Smith Creek Canyon, Snake Range, Nevada. *Trans. San Diego Soc. Nat. Hist.*, 20:1–26.
- Mead, J. I., T. R. Van Devender, and K. L. Cole. 1983. Late Quaternary small mammals from Sonoran Desert packrat middens, Arizona and California. *J. Mamm.*, 64:173–180.
- Mehring, P. J., Jr., and C. W. Ferguson. 1969. Pluvial occurrence of bristlecone pine (*Pinus aristata*) in a Mohave Desert mountain range. *J. Arizona Acad. Sci.*, 5:284–292.
- Norell, M. A. 1986. Late Pleistocene lizards from Kokoweef Cave, San Bernardino County, California. *Copeia*, 1986:244–246.
- Spaulding, W. G., and L. J. Graumlich. 1986. The last pluvial climatic episodes in the deserts of southwestern North America. *Nature*, 320:441–444.
- Van Devender, T. R., R. S. Thompson, and J. L. Betancourt. 1987. Vegetation history of the deserts of southwestern North America; the nature and timing of the Late Wisconsin-Holocene transition. Pp. 323–352 in *North America and adjacent oceans during the last deglaciation*. (W. F. Ruddiman and H. E. Wright, Jr., eds.), Vol. K-3, *The geology of North America*. The Geological Society of America, vii + 501 pp.

Accepted for publication 20 July 1988.

**The Incidence of the Cymothoid Isopod
Lironeca californica on Fishes in
Campbell Cove, Sonoma County, California**

Diane N. Waugh,¹ Tony Bennett,² and Thomas L. Dugoni³

¹*Department of Biological Science, California State University,
Fullerton, California 92634*

²*Moss Landing Marine Laboratories, Moss Landing, California 95039-0450*

³*Department of Biology, University of California (UCLA),
Los Angeles, California 90024-1606*

Abstract.—Observations were made on the infestation of fishes in Campbell Cove near Bodega Harbor, Sonoma County, California, by the cymothoid isopod, *Lironeca californica*. Three of 17 species of fishes were found to be hosts for this parasite, including the two most abundant species, *Cymatogaster aggregata* and *Atherinops affinis* (28.8% and 3.5% infestations, respectively). This parasite was found only in the opercular cavities of the infested fishes. No correlation was found between the length of the isopod and the standard length of the fish host. In *C. aggregata*, isopods were found more frequently on larger specimens. Larger isopods were found on *C. aggregata* than on *A. affinis*. In the laboratory, live isopods were observed to infest fish species in addition to those that were infested in the wild.

Members of the isopod family Cymothoidae (suborder Flabellifera) are conspicuous parasites in the mouth and on the gills of many marine fishes (Dogiel 1964; Morris et al. 1980). These ectoparasites are known to cause considerable damage to gill filaments, arches and rakers, and opercular epithelium of infested fishes (Kroger and Guthrie 1972). Species of the family Cymothoidae are armed with strong hooklike claws, which are used to cling to the gills or skin of their fish hosts (Cheng 1986). They also have mouthparts that draw the host's blood toward the mouth, affix the buccal region to the host's flesh, cut the epidermis, and prevent loss of the host's blood from the buccal field (Brusca 1981). Anti-coagulants produced in the esophageal side glands also aid in feeding for at least two species of Cymothoidae (Romestand and Trilles 1976).

The purpose of this study was to identify the parasitic isopod found in the gill cavities of fishes inhabiting Campbell Cove in Bodega Harbor and to determine the host specificity of this parasite including the frequency of occurrence and location on each species. We also measured the lengths of the isopods and the infested fishes to see if there was a size range of host that the isopod is most likely to infest. Observations of the opercular cavities of infested fishes allowed us to hypothesize as to the relationship between the isopod and its host.

Materials and Methods

The fishes were obtained in the Campbell Cove area of Bodega Harbor, Sonoma County, California, during 19–22 November 1986, using a minnow seine with 6 mm mesh. Collections were made at night during low, incoming tides.

The fishes were put into buckets and transferred live back to the Bodega Marine Laboratory, where their opercular cavities were visually inspected for isopod parasites. The standard length of each fish, and the total length of the parasite, if found, were measured. The side (right or left) of the gill cavity in which the parasite was found was noted, as was the orientation of the isopod (into or away from the current). The buckets of water used to transport the specimens were also checked after the fishes were removed for the presence of free-swimming, possibly dislodged parasites; none were found. All parasites were preserved in 70% ethanol. Voucher isopods were placed in the collection of the Natural History Museum of Los Angeles County. All infested fishes and voucher specimens of uninfested fishes were fixed in 10% formalin and then preserved in 45% isopropanol. These fish specimens were placed in the UCLA Ichthyology Research Collection. When the data were analyzed, the infestation of *Apodichthys flavidus* was not considered because only one of the two specimens captured was infested. The size of the opercular opening, which is the distance from the top of the operculum to the most anterior part of the isthmus, was measured on ten average-sized individuals of the two most common fish species, *Cymatogaster aggregata* and *Atherinops affinis*. (Average-sized individuals were fish whose standard lengths were within 5 mm of the mean for their species.) Fishes that were not preserved as vouchers were kept alive in holding tanks until all seining was completed and then released, to prevent the recapture of the same specimens.

Finally, live, free-swimming isopods were placed into a tank with live fishes of different species (*Cymatogaster aggregata*, *Atherinops affinis*, *Sebastes flavidus*, *Leptocottus armatus*, and *Hexagrammos decagrammus*) and observations regarding their interactions were made.

Results

The parasitic isopod found in the gill cavities of fishes was keyed out to be *Lironeca californica* using Schultz (1969) (confirmed by J. Morin and R. Brusca, pers. comm.). Both male and female parasites were found only on the gill arches of infested fishes.

A total of 477 fishes, comprising 17 species, were collected from Campbell Cove (Table 1). *Lironeca californica* was found on only three of these species: *Cymatogaster aggregata*, *Atherinops affinis*, and *Apodichthys flavidus* (Table 1). In most cases there was only one isopod found on an infested fish (54 cases), and never more than two (12 cases—all on *C. aggregata*). If two isopods were found, there was one in each gill cavity. *Cymatogaster aggregata* was infested significantly more often than *Atherinops affinis* (t-test, $P < 0.001$). Fifty-seven *C. aggregata* were found infested: thirty-nine isopods were in left gill cavities, thirty in right gill cavities, and in twelve fish both cavities were infested. Eight *A. affinis* were infested: four in left and four in right gill cavities. All isopods were oriented into the current.

Isopod length and fish length were not correlated for either *C. aggregata* or *A. affinis* (correlation coefficient, $r = 0.07$, and 0.01 , respectively), but isopods infesting *C. aggregata* were significantly longer (mean = 8.3 mm, S.D. = 1.6) than those (mean = 7.3, S.D. = 1.5) found on *A. affinis* (t-test, $P < 0.01$). For *C. aggregata* (Fig. 1A), infested fish were larger than uninfested fish (t-test, $P < 0.005$), but for *A. affinis* (Fig. 1B) there was no difference in size (t-test, $P > 0.1$).

Table 1. Fish species (ranked in order of abundance) collected from Campbell Cove showing frequency and distribution of infestation by *Lironeca californica*.

Species collected	N	Mean SL in mm (range) [S.D.]	Frequency of infestation
<i>Atherinops affinis</i>	230	87.8 (50–207) [14.4]	3.5%
<i>Cymatogaster aggregata</i>	191	68.5 (52–94) [5.6]	28.8%
<i>Citharichthys stigmaeus</i>	12	67.4 (46–100) [18.7]	—
<i>Sebastes flavidus</i>	12	65.3 (59–75) [5.9]	—
<i>Aulorhynchus flavidus</i>	6	114.8 (103–137.5) [12.0]	—
<i>Leptocottus armatus</i>	5	127.8 (50–182) [49.7]	—
<i>Oligocottus snyderi</i>	4	54.6 (45.5–71) [11.2]	—
<i>Scorpaenichthys marmoratus</i>	4	89.0 (65–119) [25.8]	—
<i>Apodichthys flavidus</i>	2	97.5 (69–126)	50%
<i>Artedius lateralis</i>	2	67.5 (62–73)	—
<i>Hexagrammos decagrammus</i>	2	136.4 (130–142.8)	—
<i>Lepidogobius lepidus</i>	2	75.0 (72–78)	—
<i>Gibbonsia metzi</i>	1	88.0 (88)	—
<i>Hypomesus pretiosus</i>	1	60.9 (60.9)	—
<i>Parophrys vetulus</i>	1	150.0 (150)	—
<i>Pholis ornata</i>	1	120.5 (120.5)	—
<i>Sebastes caurinus</i>	1	51.0 (51)	—
Total =	477		

The size of the opercular opening was larger for average-sized *C. aggregata* (mean = 15.2 mm, S.D. = 0.12) than for average-size *A. affinis* (mean = 11.1 mm, S.D. = 0.16) (t-test, $P < 0.005$). The gill cavities of both species of infested fishes were inspected and damage was found on the filaments of the lower parts of the first gill arches.

Finally, when live, free-swimming isopods were placed in an aquarium with live fishes, the parasite was observed to swim up to the fish and attach itself to the fish's body. It then crawled anteriorly and into the gill cavity, such that its anterior end was facing the water flow. This orientation corresponded with our earlier observations that all isopods removed from fish were found with their anterior end oriented toward the flow of water. The isopod was able to enter the gill cavities of all five species tested. *Atherinops affinis* reacted much more vigorously than the other species when the isopod tried to hook onto its body; the fish began rubbing itself on the side of the aquarium and on a rock placed in the tank. However, none of the fishes we observed was able to dislodge the isopod. Large (8.7–8.9 mm) and small (4.2–5.8 mm) isopods were placed in the aquarium, but only the small isopods swam around and were able to attach to the fishes.

Discussion

The significantly higher infestation rate on *C. aggregata* as compared to that on *A. affinis* may be attributable to a number of reasons. First, the size of the operculum was significantly larger in *C. aggregata* than in *A. affinis*, possibly allowing for an easier entry into the opercular cavity. This may also account for *C. aggregata* being infested by larger isopods than *A. affinis*. Second, it was observed that *A. affinis* and *C. aggregata* react differently in response to the isopod. Because of its vigorous response, *Atherinops affinis* may be better able to prevent

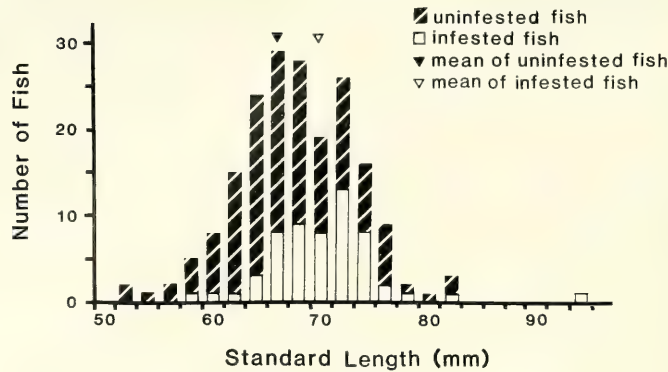
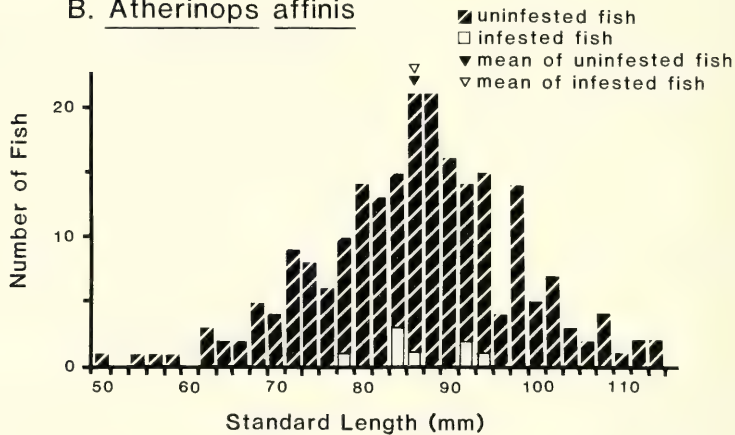
A. *Cymatogaster aggregata*B. *Atherinops affinis*

Fig. 1. (A) Length frequency of *Cymatogaster aggregata* showing that infested fish are larger than uninfested fish. (B) Standard length frequency of *Atherinops affinis* showing equal sizes for infested and uninfested fish.

the isopod from attaching or to remove it, once it has attached although this was not actually observed. Sandifer and Kerby (1983) and Moser and Sakanari (1985) report that some hosts detached the isopods by twitching and thrashing, and by quickly opening their mouths and gill covers. Third, this difference may correspond to the niches these host species inhabit. Juvenile *L. vulgaris* are geopositive, choosing more benthic hosts (Moser and Sakanari 1985). Brusca (1978) noted that *L. vulgaris* may show ecological rather than taxonomic preference for its hosts, choosing demersal, schooling fishes over more surface-oriented fishes. If *L. californica* shows the same manner of host preference, *C. aggregata* would be more likely to be attacked. Both *C. aggregata* and *A. affinis* are schooling fishes, but only *C. aggregata* is primarily demersal (Eschmeyer et al. 1983).

The lack of correlation between size of isopod and size of fish may indicate that juvenile parasites do not preferentially infest juvenile fish and then mature with their hosts. Moser and Sakanari (1985) report that juvenile *L. vulgaris* do

not show a host size preference. Trilles (1964) noted an occasional correlation between the size of the host and the isopod and postulated that this may be a result of the isopod losing its swimming ability at an early age. Newly liberated juveniles are adapted for free-swimming, but lose this ability over time (Brusca 1978, 1981; Keusink 1979; Sandifer and Kerby 1983). Our observation that only small isopods were able to swim and attach to fishes agrees with the isopods losing their swimming ability, but still we found no correlation between standard length and size. It may also be that the larger isopods lost their swimming ability because they were damaged when they were removed from the hosts.

The range and effect of damage to gill filaments caused by cymothoids is controversial. Krykhtin (1951, cited in Lanzing and O'Connor 1975) found that few of the larger and older *Leuciscus waleckii* were infested by *Lironeca amurensis*. He postulated that the parasite caused the early death of the infested carp. Sadzikowski and Wallace (1974) also found *Lironeca ovalis* more frequently on younger *Morone americana*. Contrary to these findings, our study showed that infested *C. aggregata* were larger than those that were uninfested (Fig. 1A), and the damage done by *L. californica* to the gills of these fish was probably not enough to cause their mortality. Brusca (1978, 1981) reported that cymothoids only slightly lower the well-being of the host, except when the host is stressed, as in cases of multiple infestations. The long-term biological effects of infestation by cymothoid isopods are decrease in the mean weight and size and, possibly, death of individual fish (Sadzikowski and Wallace 1974; Lanzing and O'Connor 1975; Lindsay and Moran 1976; Brusca 1978; Moser and Sakanari 1985).

Our laboratory studies indicate that this parasite is capable of infesting at least three other species of fishes besides those already found infested. *Lironeca californica* was able to infest all species of fishes that were tested. Failure to find parasites on any of these additional species may be a result of the small number of specimens obtained or to the lack of isopods on these species in the wild. Brusca (1978) and Sandifer and Kerby (1983) reported that juvenile cymothoids may attach temporarily to many different fishes that do not actually serve as hosts. The lack of parasites on these species may also be a result of the parasite abandoning its host when the host was disturbed (Kroger and Guthrie 1972; Lindsay and Moran 1976; Keusink 1979).

Early reports (Menzies et al. 1955; Lincoln 1971; Kroger and Guthrie 1972) suggested that cymothoids do not feed on blood, but rather ingest particles strained by the gills of the host or eat the host's tissues. These hypotheses are unlikely because, according to Brusca (1981), cymothoid mouthparts are adapted for feeding on blood. Bowman (1961) reported that cymothoid mouthparts are similar to the Aegidae, which have been shown to feed on blood. Other support for blood feeding includes Sadzikowski and Wallace's (1974) report of reduced and compressed gills in *Morone americana* when infested with *L. ovalis*. Also, Lindsay and Moran (1976) reported that while feeding, the gut of *L. ovalis* was filled with oil droplets mixed in a red-orange fluid, and Brusca (1978) showed the guts of male *L. vulgaris* to be packed with lysed red blood cells. Based on our observations of gill cavities, we hypothesize that the isopod is eating blood from the gill filaments. This does not exclude the possibility that some food particles strained by the gill rakers are being eaten. More observations and gut analyses are necessary to determine the diet of this isopod.

Acknowledgments

This study was supported by the U.C.L.A. Department of Biology's 1986 Marine Biology Quarter (MBQ) program at the Bodega Marine Laboratory and the U.C.L.A. Fisheries Program. We would like to thank Dr. James Morin from U.C.L.A. and Dr. Richard Brusca from the Natural History Museum of Los Angeles County for confirming the identification of the isopod. We would also like to thank R. Andrews, L. Bloch, C. Butler, D. Coleman, G. Ebesu, C. Garcia, and D. Goldstein for their assistance in the collection of fishes. Thanks also to R. D. Orton from U.C.L.A. for his help in the statistical analyses of our data and for his comments on the original manuscript. M. H. Horn provided valuable assistance with the final draft. R. H. Matson translated the French articles. Finally, and most importantly, thanks to Dr. Donald G. Buth from U.C.L.A. without whose advice this paper might never have been finished.

Literature Cited

- Bowman, T. E. 1961. Descriptions and notes on the biology of *Lironeca puhi* n. sp. (Isopoda: Cymothoidae), parasite of the Hawaiian moray eel, *Gymnothorax eurostus* (Abbott). *Crustaceana*, 1:84-91.
- Brusca, R. C. 1978. Studies on the cymothoid fish symbionts of the eastern Pacific (Crustacea: Isopoda: Cymothoidae) II. Systematics and biology of *Lironeca vulgaris* Stimpson 1857. Allan Hancock Foundation Occasional Papers, (new series), 1(2):1-19.
- . 1981. A monograph on the Isopoda Cymothoidae (Crustacea) of the eastern Pacific. *Zoological Journal of the Linnean Society*, 1981(73):117-199.
- Cheng, T. C. 1986. General parasitology. Academic Press, N.Y. xix + 827 pp.
- Dogiel, V. A. 1964. General parasitology. Academic Press, N.Y. ix + 516 pp.
- Eschmeyer, W. N., E. S. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Company, Boston. xxi + 336 pp.
- Keusink, C. R. 1979. Biology and natural history of the fish parasite *Lironeca vulgaris* (Crustacea: Isopoda: Cymothoidae). Masters degree thesis, San Jose State University. vi + 66 pp.
- Kroger, R. L., and J. F. Guthrie. 1972. Incidence of the parasitic isopod, *Olencira praegustator* in juvenile Atlantic menhaden. *Copeia*, 1972(2):370-374.
- Lanzing, W., and P. F. O'Connor. 1975. Infestation of luderick (*Girella tricuspidata*) populations with parasitic isopods. *Australian Journal of Marine and Freshwater Research*, 26:355-361.
- Lincoln, R. J. 1971. Isopod fish parasites. *Marine Observer*, 41:184-186.
- Lindsay, J. A., and R. L. Moran. 1976. Relationships of parasitic isopods *Lironeca ovalis* and *Olencira praegustator* to marine fish hosts in Delaware Bay. *Transactions of the American Fisheries Society*, 105(2):327-332.
- Menzies, R. J., T. E. Bowman, and F. G. Alverson. 1955. Studies of the biology of the fish parasite *Lironeca convexa* Richardson (Crustacea, Isopoda, Cymothoidae). *The Wasmann Journal of Biology*, 13(2):277-295.
- Morris, R. H., D. P. Abbott, and E. C. Haderlie. 1980. Intertidal invertebrates of California. Stanford University Press, Stanford, California. ix + 690 pp.
- Moser, M., and J. Sakanari. 1985. Aspects of host location in the juvenile isopod, *Lironeca vulgaris* (Stimpson 1857). *Journal of Parasitology*, 71(4):464-468.
- Romestand, M. B., and J. P. Telles. 1976. Production d'une substance anticoagulante par les glandes exocrines cephalothoraciques des Isopodes Cymothoidae *Meinertia oestroides* (Risso 1826) et *Anilocra physodes* (L. 1758) (Isopoda, Flabellifera, Cymothoidae). *Comptes Rendus des Seances de l'Academie des Sciences, Serie D: Sciences Naturelles*, Paris 282:663-665. (In French).
- Sadzikowski, M. R., and D. C. Wallace. 1974. The incidence of *Lironeca ovalis* (Say) (Crustacea, Isopoda) and its effects on the growth of white perch, *Morone americana* (Gmelin), in the Delaware River near Artificial Island. *Chesapeake Science*, 15(3):163-165.
- Sandifer, P. A., and J. H. Kerby. 1983. Early life history and biology of the common fish parasite, *Lironeca ovalis* (Say) (Isopoda, Cymothoidae). *Estuaries*, 6(4):420-425.

Schultz, G. A. 1969. How to know the marine isopod crustaceans. Wm. C. Brown Company Publishers, Dubuque, Iowa. 359 pp.

Trilles, J. P. 1964. A propos d'un fair particulier d'ethologie parasitaire chez les Isopodes Cymothoidae: la relation de taille entre parasites et poissons. Note preliminaire. Vie et Milieu, 15: 365-369. (In French).

Accepted for publication 12 October 1988.

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES ANNUAL MEETING MAY 12-13, 1989

California Lutheran University
Thousand Oaks
Ahmanson Science Center

PROGRAM FEATURES

Symposia

Mono Lake: Today and Tomorrow—A look at the biological, geological, and management aspects of this vital water resource. (Both days: May 12-13.)

Intertidal Environment of the California Channel Islands—Those who know the Islands best up-date current trends. (Friday, May 12.)

Interactive Technologies in Science Education—Can technology and education teach each other? Of course. Discover how. (Saturday, May 13.)

Special Sections

Folklore/Mythology Section—Friday, May 12. Each year we look forward to this section from the Folklore & Mythology Program at UCLA.

High School Section—Saturday, May 13. Research Training students from this year's class report on their just-finished projects. Visiting high school science students and teachers invited to attend.

**Questions? Call the Academy office—
(213) 744-3384—weekday mornings.**

Research Notes

Occurrence of *Ephydra hians* Say (Diptera: Ephydriidae) in Deep Water in Mono Lake, California

During a bathymetric survey of Mono Lake in August 1986, SCUBA divers observed and photographed the alkali fly *Ephydra hians* in deep water far from shore (Pelagos Corporation 1987). Larvae and adults were seen crawling on the lake-bottom at depths of up to 8 m and as far as 1 km from shore. Pupae ranged from less than 1 m to 11.3 m in substrate depth where a well-developed summer thermocline may have limited their vertical distribution. The divers made these preliminary observations during a geological reconnaissance of lake-bottom features and did not seek out *E. hians* or make any attempt to determine its lower depth limit. Alkali flies may occur in even deeper water. We confirmed many of these observations during a subsequent diving expedition in September 1987 to the northern, southern, and western shores of Mono Lake. The alkali fly, which was previously assumed to be restricted to less than three-meter depths, has never before been recorded in deep water (Aldrich 1912; Sturtevant and Wheeler 1954; Wirth 1971; Simpson 1976; Herbst 1986).

Mono Lake is an alkaline, terminal lake in the central California high desert at the base of the Sierra Nevada mountains. Runoff from the eastern Sierra snowpack fills its tributary streams. The bottom topography of Mono Lake is complex. Tufa towers are common and submerged boulder fields cover many square kilometers along its northern, eastern, and southern shores. Numerous diapiric, mudstone pinnacles rise precipitously from deep water. During the bathymetric and dive surveys, the alkali flies were observed on submerged boulder fields, drowned beach vegetation, and on large mats of the benthic alga *Ctenocladus circinnatus*. Throughout each of our dives, we also saw larvae drifting through the water column. Drifting behavior obviously promotes dispersal of the aquatic larval life stages.

We were unable to confirm two observations by the Pelagos divers that might partially explain the deep-water distribution of alkali flies in Mono Lake. The first observation involved the apparent unassisted descent or "swimming" of adult flies from the surface to the lake's bottom. Confirmation of such behavior would contradict previous information that adult *E. hians* require emergent objects to pull themselves down to bottom substrates (Aldrich 1912; Sturtevant and Wheeler 1954; Wirth 1971; Simpson 1976; Herbst 1986). The second unconfirmed observation involved a video recording that apparently shows an alkali fly egg-laying on one of the submerged peaks at a depth of 4 m. Although we did not observe swimming or ovipositing flies during our dives, such deep-water observations would raise some questions about the locomotory and respiratory adaptations of female alkali flies (Mono Basin Ecosystem Study Group 1987).

Aldrich (1912) claimed that emerging adults, once free of the puparium, are immediately carried to the surface by a surrounding bubble of gas formed during

pupation. This is inconsistent with our field observations of post-emergence behavior. We witnessed individuals breaking loose of the puparium and walking about the bottom for periods of up to 15 minutes without surfacing.

The observations reported here suggest that the underwater habitat of *E. hians* is extensive. Additional field work is needed to define the vertical distribution of alkali flies in Mono Lake and to identify the mechanisms they use to colonize deep water.

Acknowledgments

J. Vleck and A. Bruton of the Pelagos Corporation were the first divers to observe alkali flies in deep water at Mono Lake. A. Jahn and S. Hurlbert commented on a draft manuscript. All errors in fact or interpretation are our own.

Literature Cited

- Aldrich, J. M. 1912. The biology of some western species of the dipterous genus *Ephydra*. J. New York Entomol. Soc., 20:77-99.
- Herbst, D. B. 1986. Comparative studies of the population ecology and life history patterns of an alkaline salt lake insect: *Ephydra (Hydropyrus) hians* (Diptera: Ephydriidae). Doctoral dissertation, Oregon State University.
- Mono Basin Ecosystem Study Committee. 1987. The mono basin ecosystem—effects of changing lake level. National Academy Press, Washington, D.C., xiv + 272 pages.
- Pelagos Corporation. 1987. A bathymetric and geologic survey of Mono Lake, California. Report prepared for Los Angeles Department of Water and Power. San Diego, California, iv + 38 pages.
- Simpson, K. W. 1976. Shore flies and brine flies (Diptera: Ephydriidae). Pp. 465-495, in Marine insects. (L. Cheng, ed.), Elsevier, New York.
- Sturtevant, A. H., and M. R. Wheeler. 1954. Synopses of Nearctic Ephydriidae (Diptera). Trans. Am. Entomol. Soc., 79:151-257.
- Wirth, W. W. 1971. The brine flies of the genus *Ephydra* in North America (Diptera: Ephydriidae). Ann. Entomol. Soc. Amer., 64:357-377.

Accepted for publication 18 October 1988.

Christopher J. Foley, *Current Address: Port of Los Angeles, P.O. Box 151, San Pedro, California 90733-0151* and Brian N. White, *Los Angeles Department of Water and Power, P.O. Box 111, Room 1466, Los Angeles, California 90051.*

***Platyarthrus aiasensis* Legrand**
(Isopoda: Oniscidea: Platyarthridae)
in the Americas

The oniscid isopod *Platyarthrus aiasensis* Legrand is a small (<2.3 mm; Vandel 1962 and below) ant commensal. This species was originally described as a subspecies of *P. schoebli* Budde-Lund (Legrand 1954) but was later raised to full species status by Caruso (1968a, b). Reproduction in *P. aiasensis* is at least partially parthenogenetic (Caruso 1968b; Legrand 1953; Vandel 1962). In most populations males are absent or very rare (Caruso 1968b, 1970; Taiti and Ferrara 1980; Vandel 1962) but they can be more common, sometimes reaching frequencies of 50% (Caruso 1973).

Platyarthrus aiasensis has an extensive distribution in Europe and Africa. It has been reported from the island of Aix in France (Legrand 1954), Madeira Island and Grand Canary Island (Caruso 1970), Malta (Caruso and Lombardo 1982), Timgad in Algeria (Caruso 1970), Cape Town in South Africa (Taiti and Ferrara 1980), and numerous localities in Italy [Sicily (Caruso 1968a), the Egadi Islands (Caruso 1973), the Pelagie Islands (Caruso 1974), Ustica Island (Caruso and Lombardo 1976), Pantelleria Island (Caruso 1976), the Eolie Islands (Caruso 1968a), and the Tuscan Archipelago (Ferrara and Taiti 1978; Taiti and Ferrara 1980)].

In the Western Hemisphere, *Platyarthrus aiasensis* has been collected from three localities. On 27 December 1982 Taiti collected several specimens of *P. aiasensis* near the harbor at Dana Point, Orange County, California. On 28 February 1987 Garthwaite collected an additional 31 specimens (all female) at two locations near the Dana Point harbor: 14 at one location (lengths = 1.49-2.21 mm) and 17 at the other (lengths = 1.62-2.30 mm). In addition, on 20 October 1985 Garthwaite collected four specimens of *P. aiasensis* (all female; lengths = 1.62-2.21 mm) at Gustavia, St. Barthelemy in the Caribbean. All of these specimens conform to the descriptions of *P. aiasensis* given by Legrand (1954) and Vandel (1962). The 1987 specimens were collected from the nests of *Iridomyrmex humilis* (Mayr). This ant is native to South America but was introduced into the United States some time ago.

A single female specimen of *Platyarthrus aiasensis* (length = 1.79 mm), collected at San Antonio, Texas, is contained in the United States National Museum (USNM 87091). While this specimen has been labeled *Platyarthrus schoblii* [sic] and was reported by Schultz (1971) as *P. schoelbi schoelbi* [sic] Budde-Lund, it has been examined by one of us (RLG) and found to conform to the descriptions of *P. aiasensis* given by Legrand (1954) and Vandel (1962) with the possible exception of the reduction of rib (côte) 1 described by Legrand (1954). No collection date accompanies the National Museum specimen but it was cataloged by the museum on 21 October 1948.

Thus *Platyarthrus aiasensis*, though uncommon and sporadically distributed, has a rather extensive range in the Americas, being found on St. Barthelemy and in Texas and California.

Voucher specimens of *Platyarthrus aiasensis* from Dana Point, together with their ant hosts, have been deposited in the Santa Barbara Museum of Natural History (SBMNH 34949) and the United States National Museum (USNM 235231).

Acknowledgments

We thank Floria Parker for her help in the collection of the St. Barthelemy and 1987 Dana Point specimens and for providing literature translations, Eleanor Garthwaite for her help in the collection of the 1987 Dana Point specimens, and Roy Snelling for identifying and providing information on the ant host.

Literature Cited

- Caruso, D. 1968a. Isopodi terrestri delle Isole Eolie. Nota 1. Boll. Sed. Accad. Gioenia Sci. Nat. Catania, Serie 4, 9:351-365.
- . 1968b. Partenogenesi e spanandria in *Platyarthrus aiasensis* Legrand (Crustacea, Isopoda). Boll. Sed. Accad. Gioenia Sci. Nat. Catania, Serie 4, 9:451-457.
- . 1970. Su alcune specie del genere *Platyarthrus* (Crustacea Isopoda). Boll. Sed. Accad. Gioenia Sci. Nat. Catania, Serie 4, 10:267-274.
- . 1973. Isopodi terrestri delle Isole Egadi. Boll. Sed. Accad. Gioenia Sci. Nat. Catania, Serie 4, 12:69-94.
- . 1974. Isopodi terrestri delle Isole Pelagie. Animalia, 1:135-156.
- . 1976. Isopodi terrestri dell'Isola di Pantelleria. Animalia, 3:105-124.
- , and B. M. Lombardo. 1976. Isopodi terrestri dell'Isola di Ustica. Animalia, 3:225-233.
- , and ———. 1982. Isopodi terrestri delle Isole Maltesi. Animalia, 9:5-52.
- Ferrara, F., and S. Taiti. 1978. Gli Isopodi terrestri dell'Arcipelago Toscano. Studio sistematico e biogeografico. Redia, 61:1-106.
- Legrand, J. J. 1953. Un nouveau cas de parthénogénèse chez les Oniscoïdes (Crustacés Isopodes terrestres). C. R. Ac. Sc. Paris, 237:627-629.
- . 1954. Les Isopodes terrestres du Poitou et du Littoral charentais. Mem. Mus. Nat. Hist. Nat. Paris, Série A, 6(3):139-180.
- Schultz, G. A. 1971. *Platyarthrus schoebli* Budde-Lund new to Texas and the New World with notes on *P. hoffmannseggii* Brandt (Crustacea, Oniscoidea, Squamiferidae). Texas J. Sci., 23:297-299.
- Taiti, S., and F. Ferrara. 1980. Nuovi studi sugli Isopodi terrestri dell'Arcipelago Toscano. Redia, 63:249-300.
- Vandel, A. 1962. Isopodes terrestres. Faune de France, 66.II. Paris.

Accepted for publication 23 May 1988.

Ronald L. Garthwaite, *Institute of Marine Sciences, University of California, Santa Cruz, California 95064* and Stefano Taiti, *Centro di Studio per la Faunistica ed Ecologia Tropicali del Consiglio Nazionale delle Ricerche, Via Romana 17, I-50125 Firenze, Italy.*

DESERT ECOLOGY 1986:
A Research Symposium

Twelve papers from the Desert Studies Consortium at the Academy 1986 Annual Meeting comprise a new publication now available.

Contents

- The Coachella Solution; The Establishment of the Coachella Valley Preserve. Cameron W. Barrows.
Water Rights and Their Transfer in California. Glenn Mork.
Late Pleistocene Large Mammalian Herbivores: Implications for Early Human Hunting Patterns in Southern California. George T. Jefferson.
Comparisons of Insect Use and Chemical Defense Patterns of Two Sonoran Desert Shrubs. Charles S. Wisdom.
The Effects of Soil Disturbance by Off-Road Vehicles on the Eggs and Habitat of Playa Lake Crustaceans. C. H. Erikson, G. E. Prettyman, and J. A. Moeur.
A Review of the Life History and Status of the Desert Pupfish, *Cyprinodon maculatus*. Allan A. Schoenherr.
Plant Communities of Southern California Deserts. Robert F. Thorne.
Adaptive Significance of the Time Dependent, Pollination Related Flora Changes in California Xerophytes. C. Eugene and Mitchell B. Cruzan.
Role of Symbiotic Microorganisms in Deep Roots of Desert Flora. Wesley M. Jarrell and Ross A. Virginia.
Cactus Morphology: Effect on the Interception of Photosynthetically Active Radiation and CO₂ Uptake. Gary N. Geller and Park S. Nobel.
California Desert Bats. Patricia E. Brown.
Federal Equine Management on Federal Lands. Thomas J. McGill.

..... ORDER FORM

Make check or money order payable to Southern California Academy of Sciences, and mail to:

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES
900 Exposition Blvd.
Los Angeles, CA 90007

Please send me _____ copies of the DESERT ECOLOGY 1986 papers
@ \$29.00 per copy _____

California residents please add sales tax _____

Plus postage and handling (within the U.S.) _____ \$1.60 (postage on foreign orders will be billed)

Total enclosed (check or money order) _____

Name _____

Address _____

City _____ State _____ Zip _____

INSTRUCTIONS FOR AUTHORS

The BULLETIN is published three times each year (April, August, and November) and includes articles in English in any field of science with an **emphasis on the southern California area**. Manuscripts submitted for publication should contain results of original research, embrace sound principles of scientific investigation, and present data in a clear and concise manner. The current AIBS *Style Manual for Biological Journals* is recommended as a guide for contributors. Consult also recent issues of the BULLETIN.

MANUSCRIPT PREPARATION

The author should submit *at least two additional copies with the original*, on $8\frac{1}{2} \times 11$ opaque, nonerasable paper, double spacing the entire manuscript. **Do not break words at right-hand margin anywhere in the manuscript.** Footnotes should be avoided. Manuscripts which do not conform to the style of the BULLETIN will be returned to the author.

An abstract summarizing in concise terms the methods, findings, and implications discussed in the paper *must* accompany a feature article. Abstract should not exceed 100 words.

A feature article comprises approximately five to thirty typewritten pages. Papers should usually be divided into the following sections: abstract, introduction, methods, results, discussion and conclusions, acknowledgments, literature cited, tables, figure legend page, and figures. Avoid using more than two levels of subheadings.

A research note is usually one to six typewritten pages and rarely utilizes subheadings. Consult a recent issue of the BULLETIN for the format of notes. Abstracts are not used for notes.

Abbreviations: Use of abbreviations and symbols can be determined by inspection of a recent issue of the BULLETIN. **Omit periods after standard abbreviations:** 1.2 mm, 2 km, 30 cm, but Figs. 1–2. Use numerals *before* units of measurements: 5 ml, but nine spines (10 or numbers above, such as 13 spines). The metric system of weights and measurements should be used wherever possible.

Taxonomic procedures: Authors are advised to adhere to the taxonomic procedures as outlined in the International Code of Botanical Nomenclature (Lawjouw et al. 1956), the International Code of Nomenclature of Bacteria and Viruses (Buchanan et al. 1958), and the International Code of Zoological Nomenclature (Stoll et al. 1961). Special attention should be given to the description of new taxa, designation of holotype, etc. Reference to new taxa in titles and abstracts should be avoided.

The literature cited: Entries for books and articles should take these forms.

McWilliams, K. L. 1970. Insect mimicry. Academic Press, vii + 326 pp.

Holmes, T. Jr., and S. Speak. 1971. Reproductive biology of *Myotis lucifugus*. J. Mamm., 54:452–458.

Brattstrom, B. H. 1969. The Condor in California. Pp. 369–382 in *Vertebrates of California*. (S. E. Payne, ed.), Univ. California Press, xii + 635 pp.

Tables should not repeat data in figures (line drawings, graphs, or black and white photographs) or contained in the text. The author must provide numbers and short legends for tables and figures and place reference to each of them in the text. Each table with legend must be on a separate sheet of paper. All figure legends should be placed together on a separate sheet. **Illustrations and lettering thereon should be of sufficient size and clarity to permit reduction to standard page size; ordinarily they should not exceed $8\frac{1}{2}$ by 11 inches** in size and after final reduction lettering must equal or exceed the size of the typeset. All half-tone illustrations will have light screen (grey) backgrounds. Special handling such as dropout half-tones, special screens, etc., must be requested by and will be charged to authors. **As changes may be required after review, the authors should retain the original figures in their files until acceptance of the manuscript for publication.**

Assemble the manuscript as follows: cover page (with title, authors' names and addresses), abstract, introduction, methods, results, discussion, acknowledgements, literature cited, appendices, tables, figure legends, and figures.

A cover illustration pertaining to an article in the issue or one of general scientific interest will be printed on the cover of each issue. Such illustrations along with a brief caption should be sent to the Editor for review.

PROCEDURE

All manuscripts should be submitted to the Technical Editor, Jon E. Keeley, Biology Department, Occidental College, 1600 Campus Road, Los Angeles, California 90041. **Authors are requested to submit the names, addresses and specialties of three persons who are capable of reviewing the manuscript.** Evaluation of a paper submitted to the BULLETIN begins with a critical reading by the Editor; several referees also check the paper for scientific content, originality, and clarity of presentation. Judgments as to the acceptability of the paper and suggestions for enhancing it are sent to the author at which time he or she may be requested to rework portions of the paper considering these recommendations. The paper then is resubmitted and may be re-evaluated before final acceptance.

Proof: The galley proof and manuscript, as well as reprint order blanks, will be sent to the author. He or she should **promptly and carefully read** the proof sheets for errors and omissions in text, tables, illustrations, legends, and bibliographical references. He or she marks corrections on the galley (copy editing and proof procedures in *Style Manual*) and **promptly returns both galley and manuscript** to the Editor. Manuscripts and original illustrations will not be returned unless requested at this time. **All changes in galley proof attributable to the author (misspellings, inconsistent abbreviations, deviations from style, etc.) will be charged to the author.** Reprint orders are placed with the printer, not the Editor.

CONTENTS

Prevalence of Parasites in a Wild Population of the Pacific Harbor Seal (<i>Phoca vitulina richardsi</i>) from Gray's Harbor, Washington By Murray D. Dailey and Lori S. Fallace	1
Key to the Palaemonid Shrimp of the Eastern Pacific Region By Mary K. Wicksten	11
Late Quaternary Sciuridae from Kokoweef Cave, San Bernardino County, California By H. Thomas Goodwin and Robert E. Reynolds	21
The Incidence of the Cymothoid Isopod <i>Lironeca californica</i> on Fishes in Campbell Cove, Sonoma County, California By Diane N. Waugh, Tony Bennett, and Thomas Dugoni	33

Research Notes

Occurrence of <i>Ephydra hians</i> Say (Diptera: Ephydriidae) in Deep Water in Mono Lake, California By Christopher J. Foley and Brian N. White	41
<i>Platyarthrus aiasensis</i> Legrand (Isopoda: Oniscidea: Platyarthridae) in the Americas By Ronald L. Garthwaite and Stefano Taiti	42

LIBRARY

APR - 2 1996

NEW YORK
BOTANICAL GARDEN

COVER: Pacific Harbor Seal *Phoca vitulina richardsi*, Gray's Harbor, Washington. Photo by Murray D. Dailey and Lori S. Fallace.